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[656 .211.5 (.45)]

The main passenger station building of the new Milan station,

By ALBERTO FAVA,
ENGINEER, WORKS DEPARTMENT OF THE ITALIAN STATE RAILWAYS.

Figs. 1 to 9, pp. 539 to 549.

(*Rivista tecnica delle ferrovie italiane.*)

The wonderful enthusiasm with which, in recent years, the design and execution, of all larger transportation problems have been tackled, quickly resulted in the twenty year old problem of the re-arrangement of the railway services at Milan being completely solved on broadly conceived lines and on an ample scale.

The construction of the different parts of the buildings of the new Central passenger station having recently been put in hand, the time has come to provide without further delay the roof over the station itself.

The type of roof to be used was under consideration for a long time.

It was first of all proposed to put down twenty-four platform lines, arranged in pair, with platform 9 m. (29 ft. 6 in.) wide between each pair for use indiscriminately by passengers, luggage, parcels, Post Office bags, hampers, and other accessory services of all kinds.

The whole of these platforms were to be covered by separate steel platform roofs, carried on two lines of columns following the usual practice in the modern stations built by the Italian State Railways.

When the first enquiry was held, it was realised that, as far as possible, the interference with the movement of passengers caused by the other above-mentioned services using the platforms at the same time should be avoided. With this object in view, it was proposed to install on each platform two lifts to deal with luggage, express parcels and Post Office bags, with a network of underground passages connecting the lifts with the cloak rooms on the arrival and departure sides, with the accumulator charging shop and with the Post Office accommodation.

It was immediately realised that even with such an organisation, the movement of passengers would always be interrupted near the lifts as also by the platform trucks when in or out of use. An investigation was then made into the use of mechanical appliances, including amongst others, a system of moving belts with traps and inclined planes for handling small parcels and postal bags.

But when the design of the whole of the constructional work based on these ideas had been gone into, and the working of the proposed equipment considered in relation to the different compositions of the trains, we were obliged to admit that this also was not the best way in which to realise the desideratum of not interfering with the movement of passengers on the platforms.

It became necessary therefore to decide upon a service platform between each pair of lines equipping them with lifts, all loading and unloading, all inspection and accumulator handling taking place on these platforms, as well as watering the carriages, brake and heating inspection, and draw and coupling gear examination. As a result of this solution the number of lifts can be increased by allocating them specifically to arrivals, departures, transfers, postal service, and correlatively therewith the system of underground passages has been considerably simplified.

Owing to the little room available, it was not possible to make these service platforms very wide : they were made 4 m. (13 ft. 1 1/2 in.) wide, which allows two platform trucks to pass one another: as regards the passenger platforms, the width was fixed at 7.35 m. (24 ft. 1 in.) thereby exceeding that of the platforms originally suggested which, although 9 m. (29 ft. 6 in.) wide only left a clear width of 5 m. (16 ft. 5 in.) for the passengers. These widths were not very large : none the less they made it necessary to give up one pair of lines, reducing the number from 12 to 11.

The introduction of service platforms, owing to the restricted space available, had a very important consequence : it became necessary to give up the idea of using a separate platform roof over each platform, and substitute a continuous roof. The columns of the separate roofs, being many and close together, would in any case have taken up too much room on the passenger platforms, and would have reduced the useful width of the service platforms too much : in fact, it would have been impractical to have erected them at all as they would have impeded the movement of the platform trucks.

For the same reasons, as well as for others of a different character, the use of a covering consisting of a number of small roofs, each over a pair of lines, with the supporting pillars on the service platforms, similar to the construction used abroad in some recently built stations, did not seem desirable.

The substitution of a large span roof for the platform roofs was thus directly inspired by the requirements of the service. There is no doubt but that such a roof has many advantages as regards the passengers, who are given much better protection : in practice the platform roof, owing to the short distance it can project beyond the platform owing to the restrictions now imposed by electric traction, does not provide a very efficient protection against bad weather.

From the artistic point of view also, large span roofs are undoubtedly far more decorative and are more in keeping with the grandiose scale of the new station as a whole.

The construction of a continuous roof presents many difficulties, owing to the conditions to be complied with as regards the passenger accommodation and the underground passages of the station; all of which had all been agreed when the radical change in the roof was approved, to meet the platform type of roofing proposed, work, in fact, having been begun on them. As a result the design of the station roof had to be care-

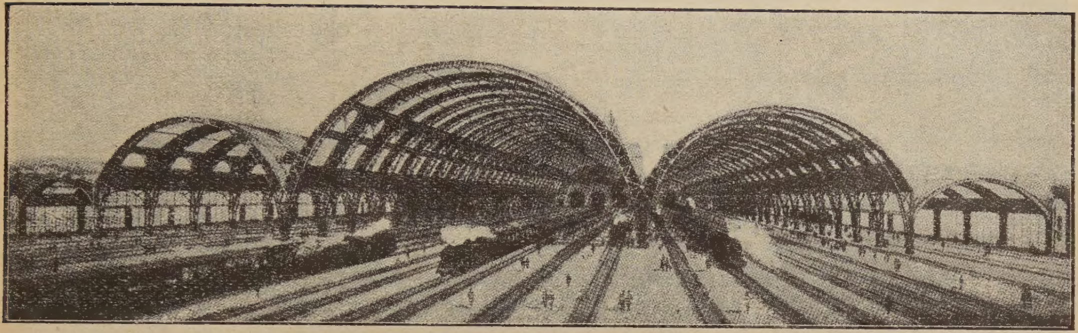

Fig 1. — General view of the station building.

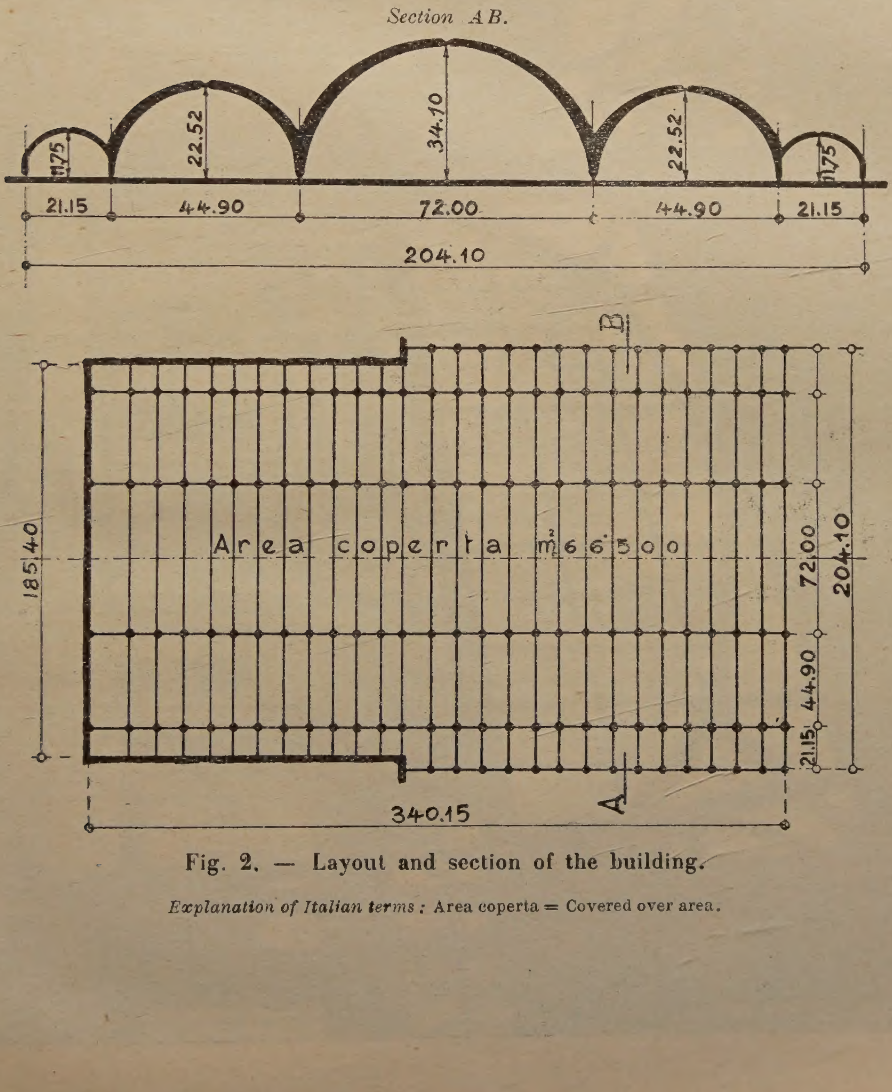

Fig. 2. — Layout and section of the building.

Explanation of Italian terms : Area coperta = Covered over area.

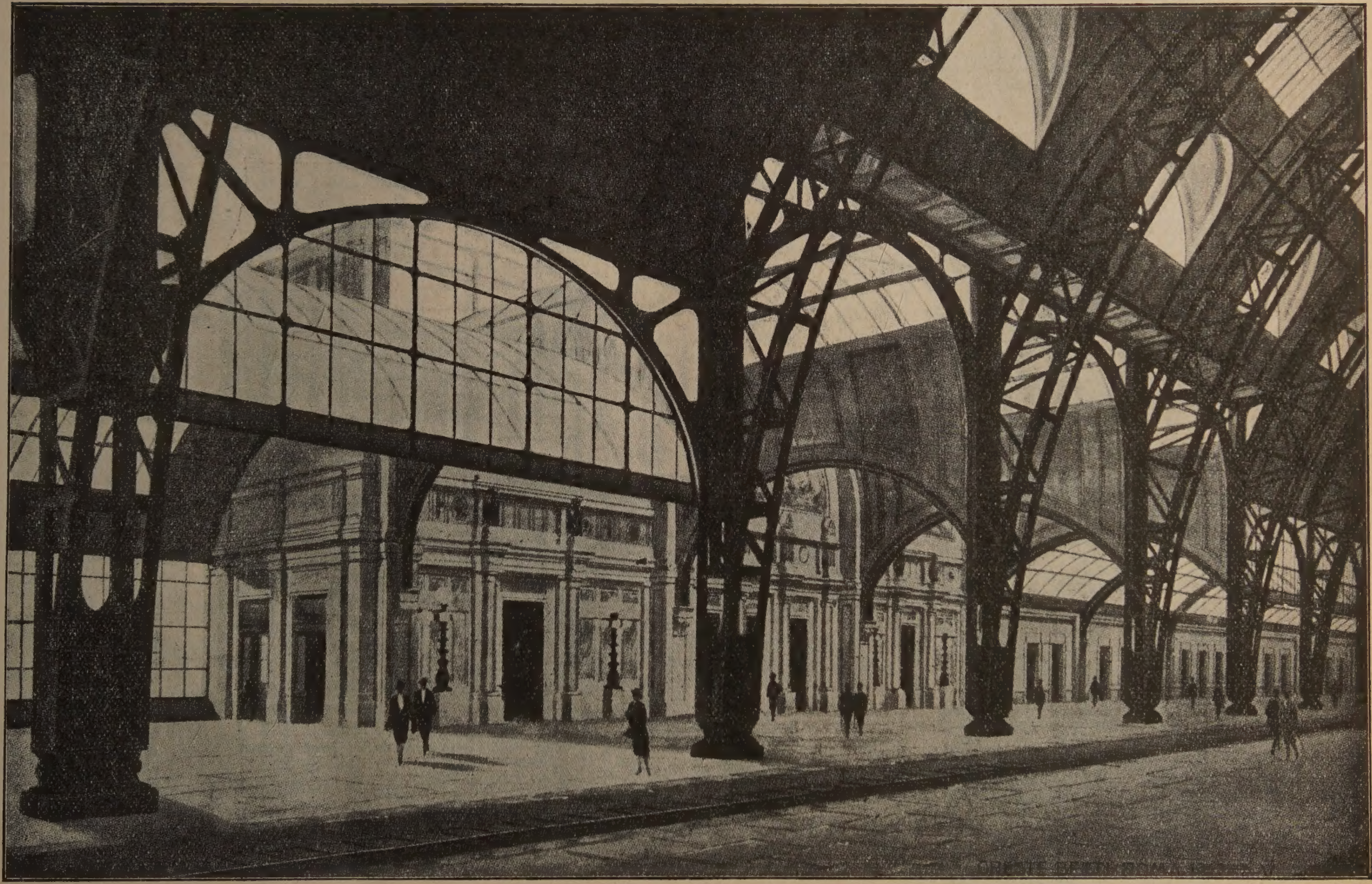

Fig. 3. — Junction arch between two main girders.

fully subordinated to the layout of the other buildings.

In a preliminary scheme, the part lying between lateral buildings was to be covered by three roofs, the middle 56 m. (183 ft. 8 3/4 in.) and the other two 64 m. (210 feet) across, these being flanked outside the lateral blocks of buildings by two other roofs of about 10 m. (32 ft. 9 3/4 in.) span.

With such an arrangement, the two large roofs abutting on the lateral buildings would have made the rooms looking on to the station much less habitable, whilst at the same time architectural requirements, would have made those looking to the outside less convenient in use. Furthermore, the use of a central roof, smaller in size than the two lateral, hardly satisfied the aesthetique point of view.

As a result, in the final design the layout was somewhat modified. Although retaining the three large roofs proposed, the span of the centre roof was increased, whilst the two adjacent arches no longer abutted on to the lateral buildings, but were kept about 10 m. (32 ft. 9 3/4 in.) from them so as to open up completely the rooms in the main building.

As regards covering over the space between the main roofs and the above-mentioned lateral buildings, the scheme provided for the construction of two small roofs which were continued over the building by two roofs of larger size.

The general layout of the roofing, governed in plan by the arrangement of the lines platforms and underground passages which, as we have already noted, had been taken in hand, was decided upon as follows: in the centre, an arched roof of 72 m. (236 ft. 2 5/8 in.) span, with a clear height at the centre of 33.50 m. (110 feet) : on each side thereof two other arched roofs of 44.90 m. (147 ft. 3 9/32 in.) span with a clear height at the centre of 22 m. (72 ft. 2 1/8 in.) : alongside these latter, alongside the two lateral buildings, two small roofs of 11.80 m. (38 ft. 8 9/16 in.) span with a maximum height of 9 m. (29 ft. 6 5/16 in.); and finally beyond the lateral buildings, two roofs of 21.15 m. (69 ft. 4 5/8 in.) span with a maximum clear height of 11.50 m. (37 ft. 8 3/4 in.).

Of the four lines of columns carrying the three main roofs, the two of the middle rest on the passenger platform, which was increased in width to make up for the room taken by them from 7.35 m. (24 ft. 1 3 /8 in.) to 8.40 m. (27 ft. 6 11/16 in.); the two side rows rest on two service platforms which were in consequence widened from 4 m. (13 ft. 1 1/2 in.) to 5.50 m. (18 ft. 1/2 in.).

The total length of the roofing was fixed at about 341 m. (1 118 ft. 9 in.), the total surface covered over being 66 500 m^2 (79 540 square yards).

The general features of the scheme for the roofs are clearly illustrated by figures 4 to 9, which shew the layout as a whole and certain of the most characteristic details. We will limit ourselves to describing some of the ideas on which the design of this important structure was based.

The main girders of the three large roofs are apparently formed of three continuous arches jointed at the supports and at the top centre. A design of this kind is statistically indeterminate owing to the continuity of the arches above the intermediate supports, and it was considered desirable to overcome this indeterminateness in order to avoid the hyperstatic thrusts resulting from changes of temperature. The system was therefore made statically determinate by introducing two further joints at the points of junction of the main girders of 44.90 m. (149 ft. 3 9/32 in.) span with those of 72 m. (236 ft. 2 5/8 in.) span. In this way, each girder is composed of an arch with three joints. The scheme provided for three joints, also for the small roof girders, so as to limit exactly the thrusts transferred to the building.

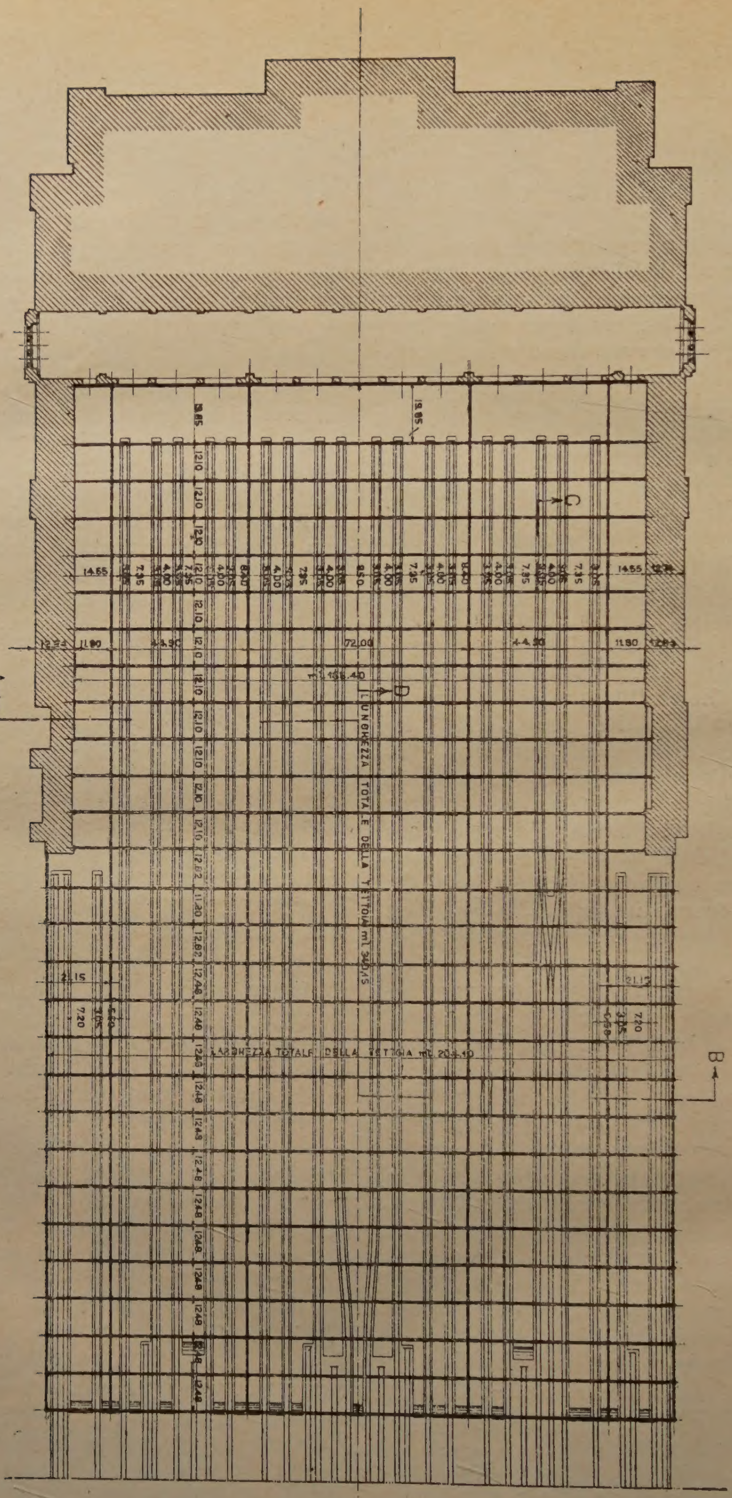
A
B
C
D
LUNGHEZZA TOTALE DELLA TETTOIA ml 340.15
LARGHEZZA TOTALE DELLA TETTOIA ml 204.10
72.00
44.90
44.90
14.55
14.55
11.90
11.90
12.24
12.24
19.85
19.85
21.15
21.15
7.20
7.20

Fig. 4. — General layout.

Explanation of Italian terms : Larghezza totale della tettoia = Overall width of the station.
Lunghezza totale della tettoia = Overall length of the station.

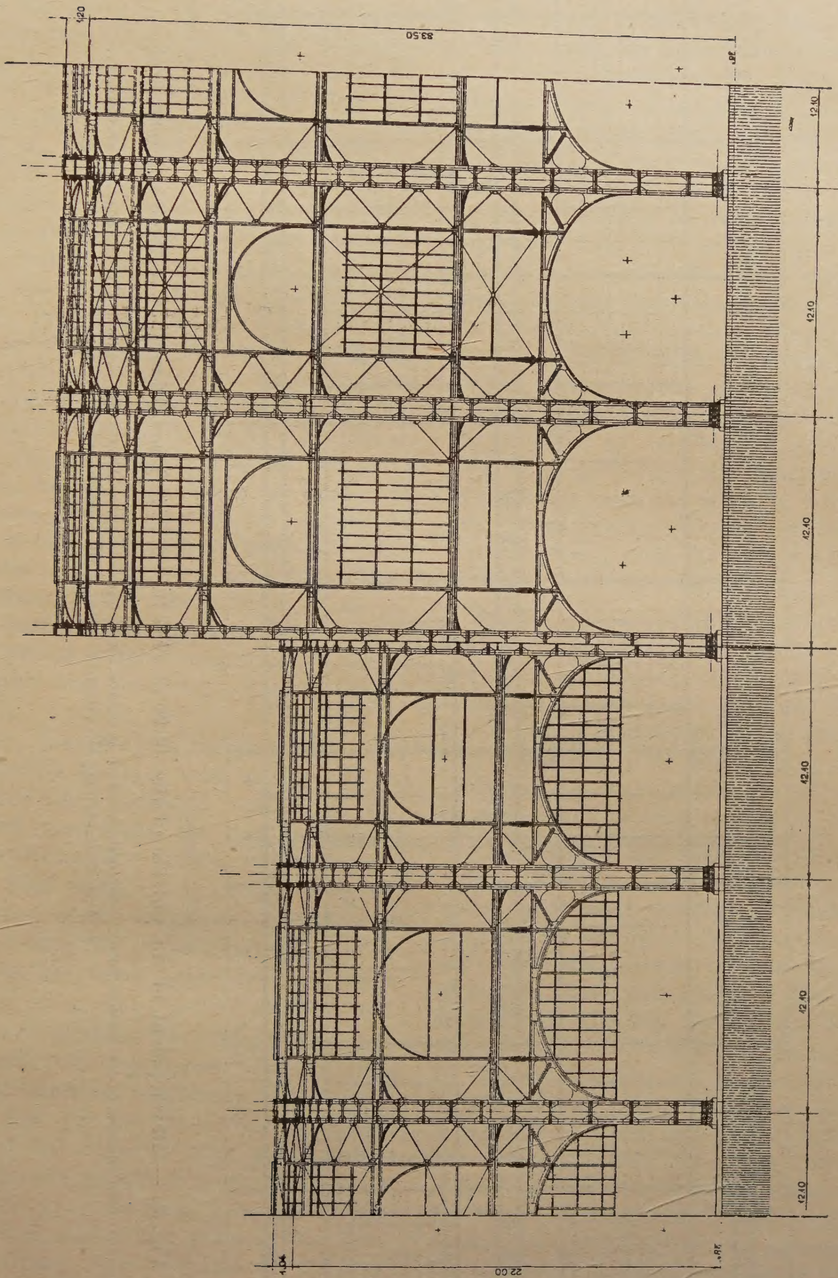

Fig. 5. — Longitudinal section CD of the 44.90 m. (147 ft. 3 9/32 in.) and 72 m. (236 ft. 2 5/8 in.) span bays.

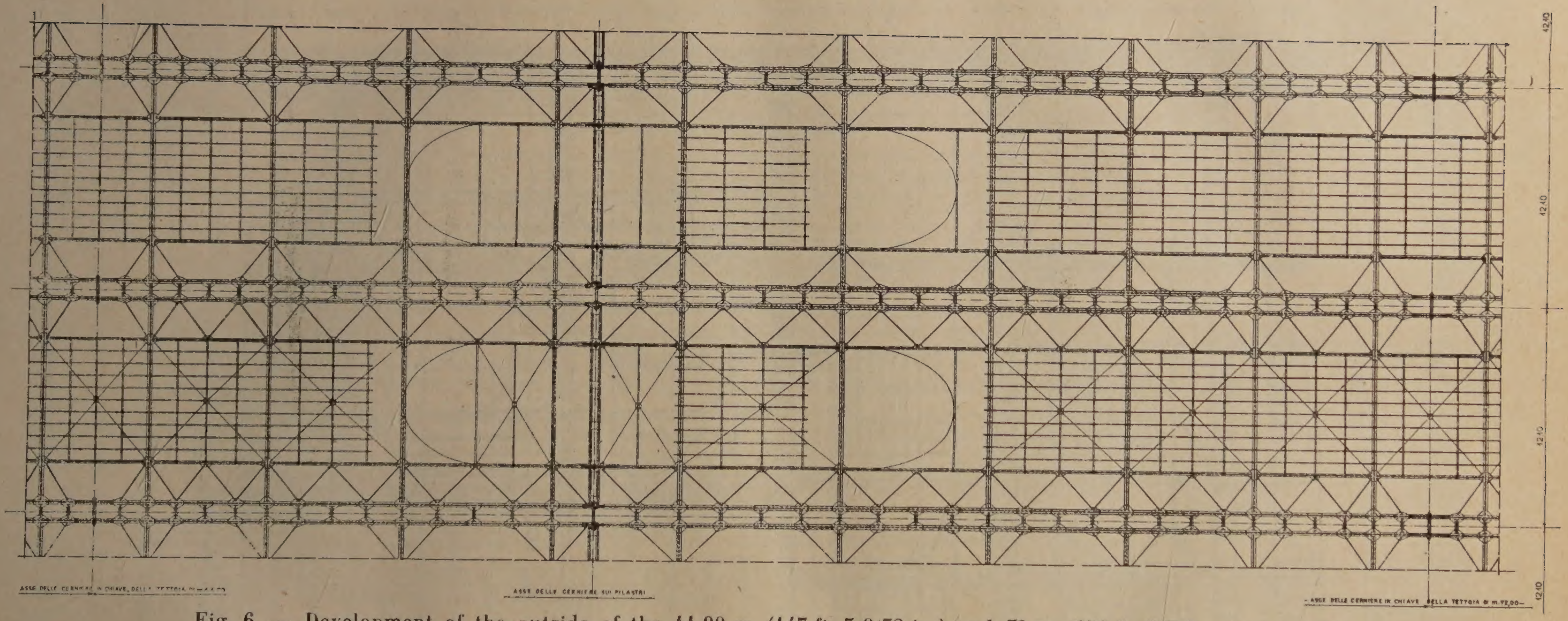
1240
1240
1240
1240
ASSE DELLE CERNIERE IN CHIAVE, DELLA TETTOIA DI m 44,90
ASSE DELLE CERNIERE SUI PILASTRI
– ASSE DELLE CERNIERE IN CHIAVE DELLA TETTOIA DI m 72,00–

Fig. 6. — Development of the outside of the 44.90 m. (147 ft. 3 9/32 in.) and 72 m. (236 ft. 2 5/8 in.) span arches.

Explanation of the Italian terms : Asse delle cerniere in chiave, della tettoia di ... = Axes of the joints at the centre of the arches of ...
— Asse delle cerniere sui pilastri = Axes of the joints above the pillars.

As the girders correspond with the construction of the lateral buidings and to the location of the subways under the station they are not spaced at equal distances apart : the centres vary from 11.80 m. (38 ft. 8 9/16 in.) to 12.82 m. (42 ft. 3/4 in.).

For constructional and artistic reasons the purlins have not been erected vertically, but radially and, as owing to the wide spacing of the main girders, they have a long span, they are subjected to reverse stresses at the lower ends, the design has made provision for these parts to carry the stresses in question. This has been achieved chiefly by scientifically varying their section as the slope increases in relation to the vertical : in addition, holding braces for fastening them to the girders have been provided at a distance of 2.30 m. (7 ft. 6 9/16 in.) therefrom; finally, the sections of the various purlins have been tied together at these points with strong braces so as to overcome any tendency of the sections to turn.

Every fourth span, the purlins have a free sliding joint so that, as regards the effect of the expansion caused by temperature variations, the roof is divided into sections of a length not exceeding 50 m. (164 feet).

In view of the magnitude of the work and the long life it must have, ample allowance has been made for any overloading.

The calculations were made in accordance with two hypotheses : first of all, a vertical loading uniformly distributed, of 120 kgr. per m^2 (24.60 lb. per square foot) of the covered area was taken : the different members were checked on the basis of a vertical load of 50 kgr. (10.25 lb.) and at the same time a horizontal thrust due to wind of 150 kgr. per m^2 (30.75 lb. per square foot) of the area usually acted upon.

In view of previous exeperience, which shewed that the lighter members of roofs exposed to the sulphurous gases of locomotives were subject to quick corrosion, thereby limiting the life of many buildings which in the essential parts, ought to have had a much greater life, it was considered desirable to avoid using in any load carrying parts a thickness of less than 10 mm. (25/64 inch) even when much thinner sizes would have met the theoretical requirements. Furthermore, the use of small trellis work was not permitted in the arches of the smaller girders, the arcades and braces, all of which were made of sections of plain web. The large girders of the roofs alone, in accordance with the scheme, were built as trellis girders, because in this case without heavy cost the trellis work can be built up of very thick bars.

By this almost complete avoidance of trellis work, it is also thought a considerable improvement has been achieved from the artistic point of view, through the resulting simplicity of the lines, and the avoidance of the interlocking and interlacing of the members so often seen in roofs, even of smaller size.

As a result of the very careful investigation into the project based on the above-mentioned principles, which were inspired by the desire that the life of the structure should not be sacrificed for any immediate small saving that might have been effected, the weight of iron for all the members, excepting only those of the clerestories and of the windows, is as follows : for the 72-m. (236 ft. 2 5/8 in.) roof, 145 kgr. per m^2 (29.70 lb. per square foot) of area covered: 120 kgr. per m^2 (24.60 lb. per square foot) for the 44.90 m. (147 ft. 3 9/32 in.) roof : 84 kgr. per m^2 (17.20 lb. per square foot) for the small roofs, an average of 123 kgr. per m^2 (25.19 lb. per square foot) of the covered area.

Principal dimensions of certain large railway stations.

NAME OF THE STATION.	TYPE OF STATION.	Width, in metres (feet and inches)	Length, in metres (feet and inches)	Height under centre, in metres (feet and inches)	Area covered in square metres (square feet)
Lille	Arch.	65.35 (214 ft. 5 in.)	162.84 (534 ft. 3 in.)	...	10 641 (114 542)
Antwerp	Arch.	64.94 (213 feet)	175.00 (574 ft. 2 in.)	32.50 (106 ft. 8 in.)	11 365 (122 336)
Cologne	3 arches.	63.50 (208 ft. 4 in.)	255.00 (836 ft. 7 in.)	24.00 (78 ft. 9 in.)	48 577 (522 897)
Berlin-Anhalt . . .	Arch.	62.50 (205 feet)	168.00 (551 ft. 2 in.)	15.00 (49 ft. 2 in.)	10 500 (113 025)
	Central arch.	59.00 (193 ft. 7 in.)	174.00 (570 ft. 10 in.)	28.65 (94 feet)	...
Dresden	2 side arches.	30.75 (100 ft. 11 in.) 32.00 (105 feet)	240.00 (787 ft. 5 in.)	16.75 (54 ft. 10 in.)	27 534 (296 384)
	A small arch.	9.50 (31 ft. 2 in.)	240.00 (787 ft. 5 in.)	...	...
Bremen	Arch.	59.30 (194 ft. 7 in.)	131.00 (429 ft. 9 in.)	27.10 (88 ft. 11 in.)	7 768 (83 617)
Frankfort-on-Main . .	3 arches.	56.00 (183 ft. 9 in.)	186.00 (610 ft. 3 in.)	28.60 (93 ft. 10 in.)	31 248 (336 363)
Bordeaux-St. Jean . .	Arch.	55.90 (183 ft. 5 in.)	296.96 (974 ft. 3 in.)	25.80 (84 ft. 8 in.)	16 600 (178 687)
Marseilles-St. Charles .	Arch on walls.	54.92 (180 ft. 1 in.)	159.20 (522 ft. 4 in.)	26.74 (87 ft. 9 in.)	8 743 (94 112)
Leipsig	6 large arches.	From 45 to 42.50 (147 ft. 8 in. to 139 ft. 5 in.)	203.90 (669 feet)	20.00 (65 ft. 7 in.)	60 150 (647 472)
	2 small arches.	15.00 (49 ft. 2 in.)	203.90 (669 feet)	...	
Turin	Arch.	47.00 (154 ft. 3 in.)	137.00 (449 ft. 5 in.)	30.00 (98 ft. 9 in.)	6 439 (69 311)

It should be observed that in the main station building at Hamburg, so far as we know, the only one amongst European railway stations (excluding England) having dimensions comparable with those of the new station at Milan, the weight of the roof carrying steel work was 135 kgr. per square metre (27.65 lb. per square inch), although the outside was covered with much lighter material, namely corrugated iron sheets.

As regards the various parts making up the covering, it will be noted that to ensure the interior being well lighted, almost one half has been glazed : the scheme includes large clerestories with reinforced glass and special glazing without putty.

Care was taken to balance the glazed and opaque areas; and in order to give a sense of movement to the large roofs, it was arranged to use in addition in each roof two lines of large lunettes.

These were not provided for decorative purposes alone : they will materially assist the ventilation of the building and the extraction of smoke in conjunction with a series of ventilators to

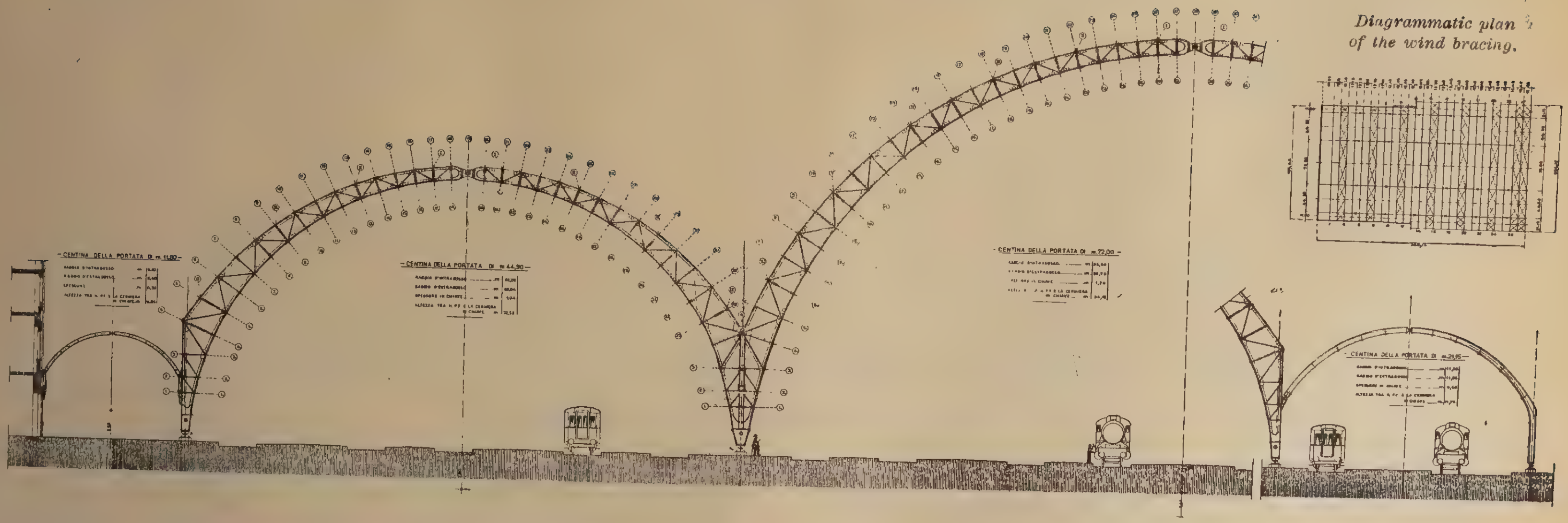
Diagrammatic plan of the wind bracing.
- CENTINA DELLA PORTATA DI m. 11,80 -
- CENTINA DELLA PORTATA DI m 44,90 -
- CENTINA DELLA PORTATA DI m. 72,00 -
- CENTINA DELLA PORTATA DI m. 21,95 -

Fig. 7. — Cross section on AB of the general plan (fig. 4).

Explanation of the Italian terms: Altezza tra il P. F. e. la cerniera in chiave = Height of the joint at the top above rail level. — Centina della portata di ... = Main girder of ... of span. — Raggio d'estradosso = Radius of the outer roof. — Raggio d'intradosso = Radius of the inner roof. — Spessore = Thickness.

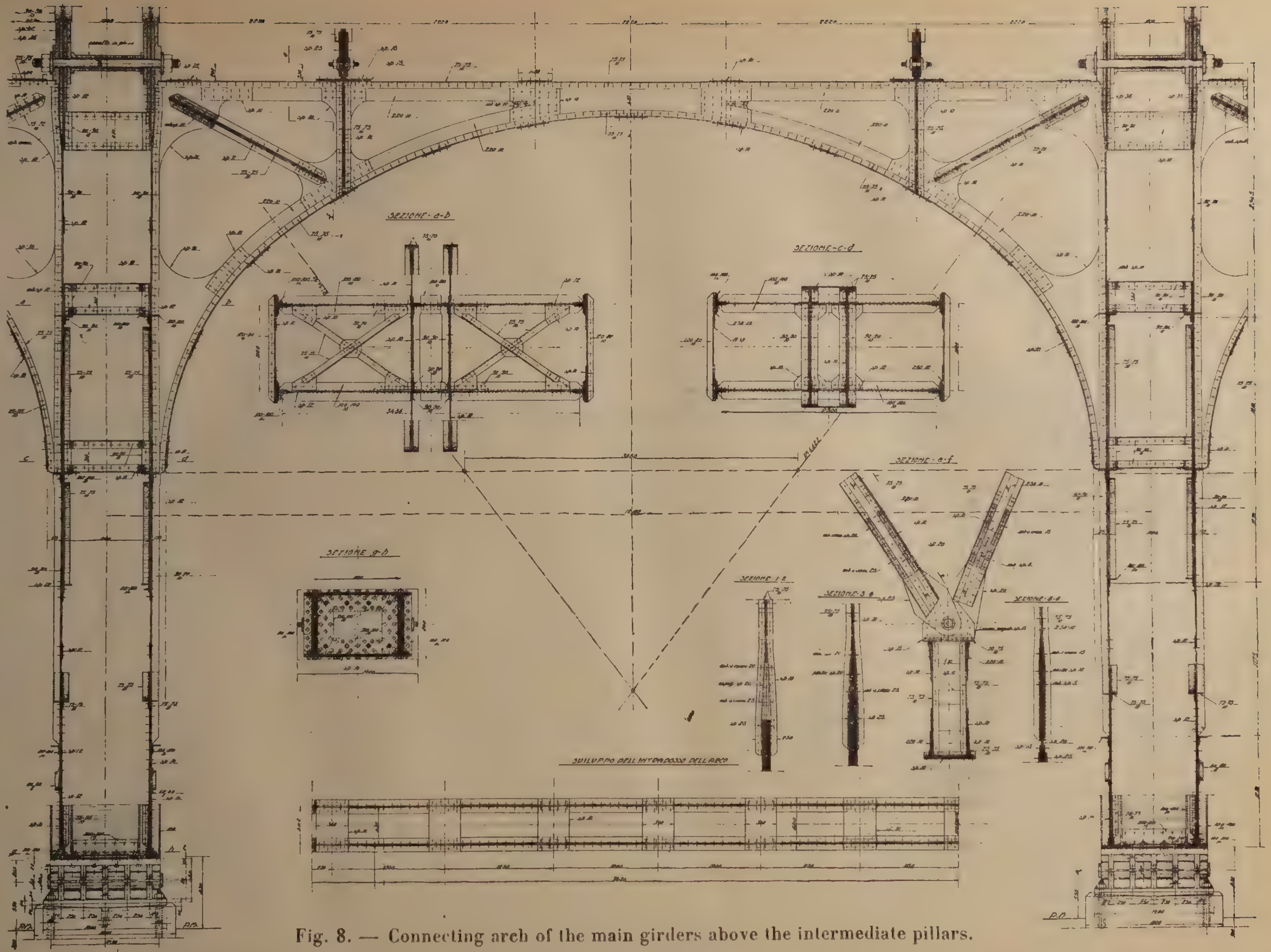

Fig. 8. — Connecting arch of the main girders above the intermediate pillars.

Explanation of the Italin terms: Canotto in ghisa = Cast iron ring. — Coprig. = Joint cover. — Imb. a cuneo = Conical cover. — Piastre = Plates. — Sp. = Thickness.
Sviluppo dell'intradosso dell'arco = Development of the inner roof of the arch.

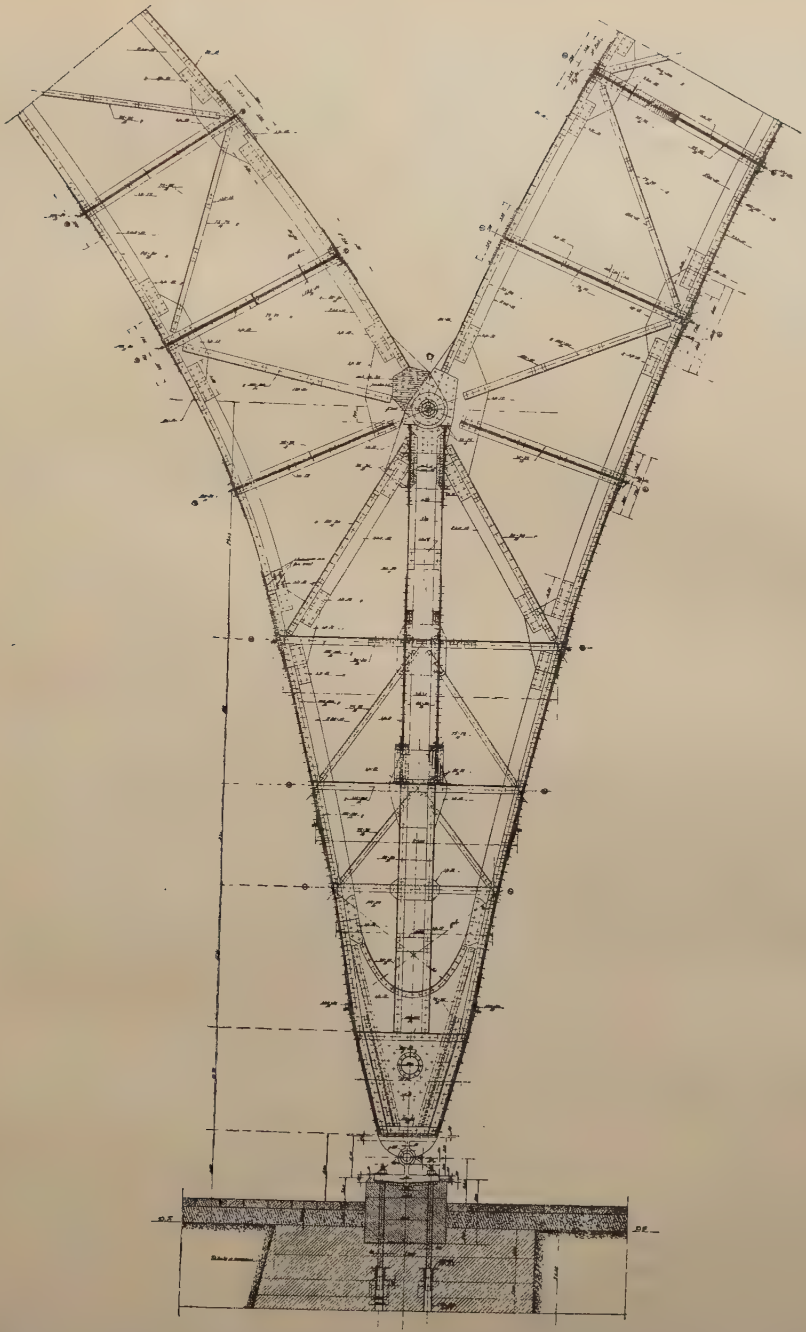

Fig. 9. — Pillar between the main girders of 72 m. (236 ft. 2 5/8 in.) and 44.90 m. (149 ft. 3 9/32 in.) span.

be fitted along the top of the arches in the positions found most convenient at the time.

For covering the parts, not to be glazed, various materials were considered.

Corrugated iron sheets were put aside at once, in spite of their extreme lightness. Practical experience has shewn that galvanised sheets used to cover in stations are subject to rapid deterioration, whilst there is insufficient knowledge of the lead or aluminum covered sheets now being tested by the Italian State Railways.

The use of slabs of reinforced concrete made from pumice stone, now largely used in Germany, was considered, and a number of tests were made or them : it was finally decided not to use this material, although it is now made in Italy, as, in spite of the pumice stone in it, it is relatively heavy.

The use of reinforced hollow tiles, Perret, Italia and other patterns, although they are suitable for industrial purposes, would have resulted in too crude a covering, which would not have harmonised with the character of the structure, even ignoring the doubt there is as to their life in service.

In the approved scheme, provision was made for a covering in artificial slate sheets carried on a strong wood framing with panels and frames. A construction of this kind supported on wood, sufficiently light, and lending to the whole a very decorative appearance, ought not to give rise to much anxiety, either as regards fire, which may be considered as impossible in view of the great height, or as regards maintenance, which in our other stations is not very heavy. The proof is that in other countries, an outer roof in wood is often the one most frequently used for stations, although so many other materials are now available. None the less, it remains to be seen if the part in wood cannot be completely eliminated.

To end up, it should be noted, as regards the final operations, that in view of the unusual size of the structure, immediately the metal framework was erected, full size models of the wood roofing, the windows, and the lunettes were made.

The order for the construction of the steel work has recently been placed with the « Società Nazionale Officine di Savigliano », at Turin, for the centre arch, the « Società Cantieri Navali ed Acciaierie », at Venice, and the Aurora Works of G. Della Carlina, Engineer, for the other bays. The contracts for the other work will be let shortly. If, as there is no doubt it will, the work proceeds as expected, the grandiose structure will be completed in 1929.

[625 .143.2]

The manufacture of sound rails by the Courthéoux method of rolling,

By Louis PICHARD,

ENGINEER OF THE HAGONDANGE WORKS.

Figs. 1 to 10, pp. 552 to 557.

(*Le Génie Civil.*)

The problem of the manufacture of rails is one of the most important before the heavy steel industry. In this matter, everything should be directed towards perfection, seeing that the rail not only acts as *main girder,* but also is subjected to very heavy duty due to the fact that it is at the same time *a track upon which rolling occurs.*

These two features or functions were definitely separated when rails were first used as, in the mines, the track was built up of pieces of wood covered by a thin strip of metal; at the present time, they are still sometimes separated more or less completely as, for example, when crossing bridges, in which case the rail rests either on the stringers or directly on the main girders of the bridge; usually, however, the two functions are combined, and this combination is the difficult part of the problem.

The effect of the shape is very definite: one of the flanges of the girder is enlarged into a massive head; its effect is still greater on the strength of the metal, as the decision to use the hard quality is solely due to the consideration given to the question of rolling wear. Now, with the hard quality, we very quickly get a considerable degree of segregation, this segregation preponderating in the base of the head, or even extending through the greater part of it. As, furthermore, the head is large, it is the seat of internal stresses due to irregular cooling, as we have shewn in an article in the *Génie Civil* of the 29 January 1927. Finally, the top layer of the rail head, the only part which can be more or less completely sound, is pressed out, gathered up, heated and even tempered, in fact is very much maltreated in use : and it is this head which is too often likely to be defective that has to stand a fatigue of the order of 30 stresses to the second (¹).

This explains why the statistics shew that, outside failures at the joints, there are practically only failures originating in the head and very often from the interior thereof. We think that, except in cases when the rail foot is also very massive and then has from many points of view a liability to weakness similar to that of the head (oval mark in the foot in America) if a fracture start from the foot it is the result of a local defect, the position of which is due to chance (²).

It is therefore the head of the rail that should receive attention. There are two ways of preventing the stress it is subjected to from giving rise to defects : first by assisting it and secondly by improving it.

It can be assisted in certain special cases by relieving it completely of its rôle of girder. For example, a section of line subjected to frequent slipping and at the same time to the passage of trains at high speed is a matter of great anxiety for the permanent way staff : slipping gives rise to cracks which grow if the metal be unsound and because it works in tension. If such a section of line were carried on properly cross-braced longitudinal members, each rail resting on a continuous bearing, to some extent elastic, there would no longer be localised reactions from the sleepers, nor would the head be subjected to tensile stresses at the rate of 30 to the second. We realise that an arrangement of permanent way of this kind has its objections, but it may have to be considered in particular cases of this kind.

As regards improvements, we will not quote those being taken to get better metal, as even a brief description thereof would be outside the scope of this article, and furthermore most of them can be

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(¹) See *Génie Civil,* 29 January 1927 (vol. XC, No. 5, p. 122); see also *Bulletin of the International Railway Congress,* number for August 1927, p. 686.

(²) The breakages occurring when testing rails, in accordance with the post-war specifications, and which have been investigated by the Committee on Rails, are almost entirely fractures starting in the head. Segregation therein (bar from the head of the ingot) or the inclusion of mild steel (bar from the foot with insufficient discard) are most frequently the predominant causes of these fractures.

made at the same time as those we will now mention.

First of all, as affecting the head, we will consider the heat treatment thereof. Whether it be the Sandberg process in use at the Hagondage Works, or that of Neuves-Maisons, it was thought the treatment would only improve the metal in the head as a whole, and in fact produce a difference of hardness between the web and the rolling surface. The difficulty lay in getting a graduated treatment with a subsequent automatic annealing : the readers of the *Génie Civil* are aware of the way this has been done at these two Works (1), but it may be said that treated or not the rail with unsound head remains suspect. As we cannot prevent a rail with unsound head from being passed, in spite of the tests, which cannot be multiplied indefinitely, how are we to make systematically impossible the presence of segregation in the rail head ?

Mr. Courthéoux, Manager of the Rolling Mill at the Hagondange Forge and Steel Works, has recently solved this problem by keeping the head well away from the centre of gravity of the zone presumed to be segregated and leaving in it only sound metal.

Even from the tops of the ingots, rails are got with sound heads by cutting the ingots in two in the direction of their length, and by keeping in each half for the making of the head the two opposite faces before cutting.

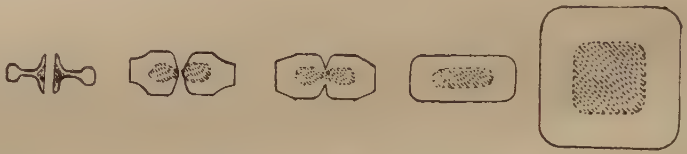

Fig. 1. — Parting the ingot.

The ingot, first of all rolled as a bar, is separated into two parts by rolling (fig 1). It is first of all passed through a parting roll which roughs out the work of cutting and starts in addition to roll down the angles; a second parting roll completes the separation and also rolls out the web which, in addition to ensuring greater regularity in rolling, has the advantage of making it impossible subsequently to change the faces of the resulting blooms.

The macrograph of a rail with only 8 % discard reproduced below (fig. 2) shews that the web of the rail is also improved, especially in the upper part, as it was expected, seeing that it is made from the metal farthest from the centre of the ingot. This difference will be particularly appreciable at the joint, the defects of which belong to two classes. In the first group, fissures at 45° start from the top of the holes which have been hammered by the bolts, whereas the interior fissures only occur when the wear of the whole assembly is very far advanced (fig. 3) : in the second group, the hammer of the wheels on the rail end has the effect of splitting transversely the top, the rolling surface usually fairly sound generally remaining whole at first (fig. 4). In the two cases it was of great importance to make the top of the web sound.

On the other hand, the rail foot has to suffer. Before estimating to what extent, it should be noted that it is only

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(1) The Sandberg process was described in the *Génie Civil* of 4 January 1919 (vol. LXXIV, No. 1, p. 15) and the results obtained were given in the *Génie Civil*, 10 January 1925 (vol. LXXXVI, No. 2, p. 144).

The Neuves-Maisons hardening process was described in the numbers of the *Génie Civil*, 7 February 1925 (volume LXXXVI, No. 6, p. 140) and 5 June 1926 (vol. LXXXVIII, No. 23, p. 509).

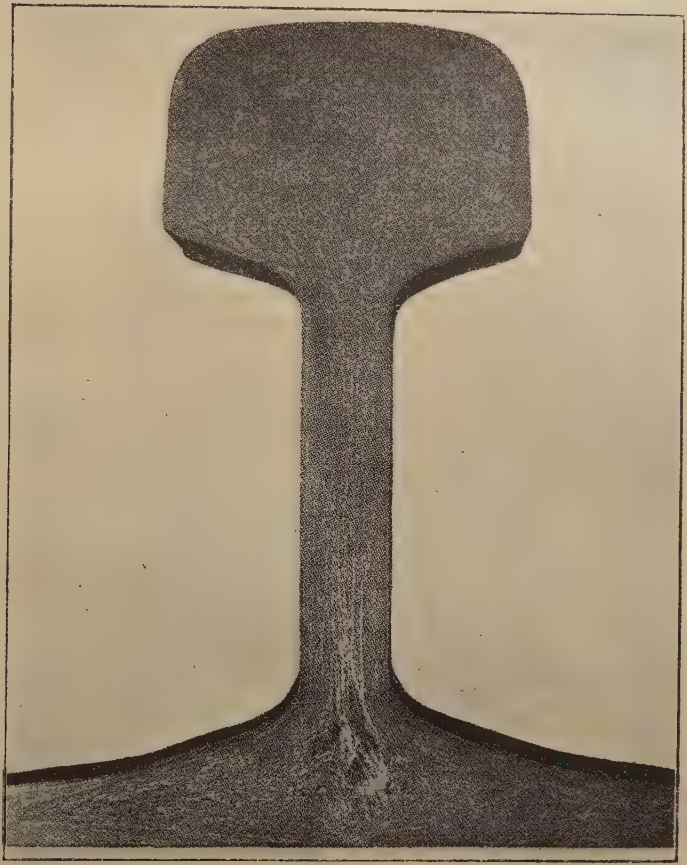


Fig. 2. — Section of a rail of 8 % discard.

(Etched by Oberhoffer's reagent.)

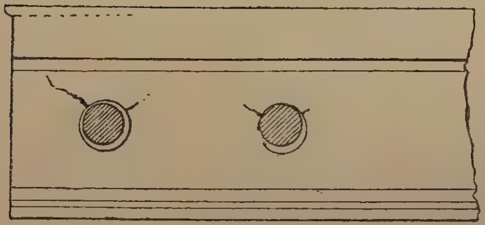


Fig. 3.
Fissures round the holes.

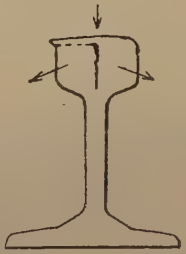


Fig. 4. — Splitting
of the rail head.

affected in its central part and that the wings remain formed of sound metal.

We should, however, consider if this foot, possibly defective in the same way and place as the head, may not cause as much trouble as that eliminated elsewhere. We hardly think so, as having no rolling surface it becomes a part of a girder : furthermore, the metal is very much worked and owing to its thinness its « thermic history » is better than that of the head. In spite of these advantages, there will probably be Courthéoux type rails with defects in the foot : some of these will be observed in time (this will be easier to do than in the case of the head) but it is likely some will not be noticed in time. Will they increase the proportion of broken rails ?

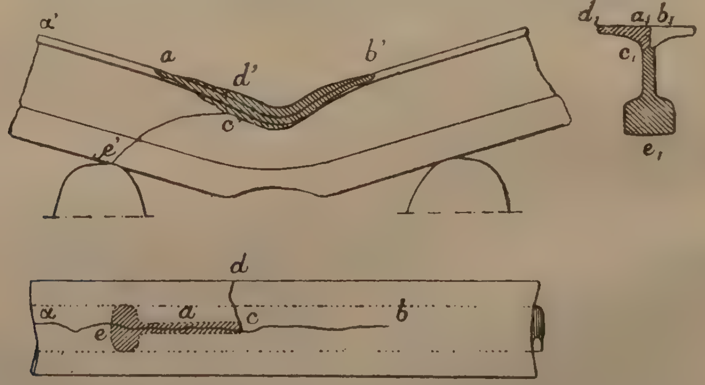
With the rails now in use, out of 100 breakages 50 occur at the fish plates, 45 begin in the head, and only 5 in the foot.

The Courthéoux rail will be better as regards the first case, as we have just shewn. The cases of failure in the head and foot remain : the great disproportion of these fractures and all the reasons we have given on the shape and stresses in these parts of the rail make us think that their total will be certainly less or even a minimum with the Courthéoux rails.

Several years of actual use alone can confirm or disprove our argument. The railway companies will certainly agree to test the new type of rail which, furthermore, has already given tangible proof of its superiority under the drop tests as the following table clearly shews.

Furthermore, the introduction of the Courthéoux rail should result in a further investigation into the formula for the drop test which was got out in order to find rails presumed to be defective under the rolling surface : the need for this test will be, in fact, of secondary importance, and it will probably become more necessary to shew up those rails with the foot too defective, that is, to introduce a test of abrasion of the undoubtedly sound wings and to drop the tup on to the head of the rail so as to put the rest of the foot into tension.

On the other hand, the Courthéoux rail, which it has been said will get found the present drop test, can be placed at a disadvantage if the test is carried too far : in practice it is known that the tup rebounds and the rail rocks over : when the tup falls again it strikes and bends one wing, and blow by blow the trouble increases until we get a « split foot » a defect that frequently results in a premature and abnormal fracture, known as « fracture on support » (figs. 5 to 7) : the



Figs. 5 to 7. — Fracture « on support ».

Result of drop tests. (French standard specifications. **Machined bar.**)

Notes.	Quality.		Discard,	First blow, 4.40 m. (14 ft. 5 1/4 in.)	Other blows from 6 m. (19 ft. 8 1/4 in.).															*Observations.*
	Kgr. per square millimetre.	English tons per square inch.			2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	
			Per cent.																	
	70.6	44.83	4 to 6	8	17	24	30	35	+											
	70.0	44.45	4 to 6	8	17	25	31	+												
	63.4	40.26	4 to 6	8	19	23	35	+	...	...	...	...	...	...	...	...	...	...	...	(R indicates fracture).
	62.7	39.81	4 to 6	8	18	27	36	+												
	73.3	46.54	4 to 6	8	17	24	31	+												
	80.0	50.80	4 to 6	8	17	24	30	+	...	...	...	...	...	...	...	...	...	...	...	(+ tests not finished).
	75.3	47.81	4 to 6	8	18	25	32	+												
	80.0	50.80	4 to 6	8	16	22	29	+												
Test pieces taken 2 m. (6 ft. 6 3/4 in.) apart from the same bar.	70.0	44.45	5	8	14	21	27	30	35	40	44	48	54	R						
	70.0	44 45	8	8	14	21	26	31	36	38	R									
	70.0	44.45	11	8	15	21	27	32	37	40	44	48	52	55	57	R	...	...	...	Broken at the support.
	70.0	44.45	14	8	15	21	26	31	36	40	44	48	51	55	58	60	65	69	R	
	70.0	44.45	17	8	15	22	26	31	35	40	42	45	47	R						
	70.0	44.45	20	9	15	20	25	31	36	39	41	43	R							
	64.7	41.08	20 to 22	9	18	29	35	43	51	+										
	77.3	49.08	20 to 22	8	16	22	27	34	40	R	...	...	...	...	...	...	...	...	...	Broken at the support.
	82.6	52.45	20 to 22	6	14	20	25	30	R	...	...	...	...	...	...	...	...	...	...	Broken at the support.
	76.6	48.64	11 to 12	8.5	15	23	29	R												
	76.6	48.64	11 to 12	9	16	22	28	34	41	45	R									
	78.6	49.91	11 to 12	9.5	17	24	28	R	...	...	...	...	...	...	...	...	...	...	...	Broken at the support.
	78.6	49.91	11 to 12	8.5	17	24	32	+	...	...	...	...	...	...	...	...	...	...	...	Foot broken
	76.6	48.64	11 to 12	7	16	23	29	37	R											
	77.3	49.08	11 to 12	8	16	21	28	34	39	45	49	R								
	77.3	49.08	11 to 12	8	17	23	29	36	R	...	...	...	...	...	...	...	...	...	...	Broken at the support.
	78.6	49.91	11 to 12	7.5	14	22	31	33	36	R										
	78.6	49.91	11 to 12	7	16	23	28	R	...	...	...	...	...	...	...	...	...	...	...	Broken at the support.
	78.6	49.91	11 to 12	8	15	22	28	R												
	77.3	49.08	11 to 12	8	16	23	29	36	42	46	51	57	61	R	...	...	...	...	...	Broken at the support.
	77.3	49 08	11 to 12	9	17	24	30	38	44	51	+									
Heat treated.	68.7	43.62	20 to 22	9	17	21	28	33	38	41	43	+								
	71.3	45.27	20 to 22	9	15	21	27	30	°/° +											
	84.0	53.34	20 to 22	8	16	23	R	...	...	...	...	...	...	...	...	...	...	...	...	Broken at the support.
	89.3	56 70	20 to 22	7	15	21	27	33	36	39	+									
	84.6	53.72	20 to 22	8	15	22	27	34	39	R										

longitudinal fissure *ab* gives birth to two transversal branches : one *cd* cuts across one of the wings, and the other *ce* cuts through the web and the head to end at the support. Personally, we had expected this particular weakness of the Courthéoux rail under the drop test now specified and were pleased to see that in spite of everything it took a long time to reveal itself.

The behaviour of the rail in service is very different from that of a rail with the foot cracked by repeated blows, and in conclusion we are convinced that Mr. Courthéoux' method will be considered of sufficient value for the Railway Companies to give it extended applications.

⁂

We think it will be of value to reproduce below the letters Messrs. Courthéoux and G. Charpy wrote to the Editor of the « Génie Civil » after the publication of the article by Mr. Pichard.

The manufacture of sound rails.

The Editor of the « *Génie Civil* »,

In your number of the 31 December 1927 you published an article by Mr. Louis Pichard entitled : « *The manufacture of sound rails by the Courthéoux method of rolling* ». This article was noticed by my former Chief, Mr. G. Charpy, Member of the « Institute », who has called my attention to the fact that he described as long ago as 1918 the method of rolling I had thought I had discovered myself. The examination of the patent he has sent me leaves no doubt as to its priority which I fully admit, and which I hope you will have the kindness to bring to your readers' notice by inserting this letter.

I think I can add that if I have come into contact with Mr. Charpy in this work, it is undoubtedly due to the fact that my work has been constantly inspired by the principles he shewed me to be necessary if steel products of high quality are to be obtained, when, as a young Engineer, I was working under him.

I remain, etc.,

Courthéoux,
Engineer at the Hagondange Works.

The Editor of the « *Génie Civil* »,

I wish to thank you for having shewn me Mr. Courthéoux' letter, which he wrote of his own accord when I sent him my earlier article. The similarity of the ideas at which we have arrived independently is really very striking. I much regretted having to disillusion an able and keen engineer, although so far as I was concerned I had the satisfaction of noting a new experimental verification of the general principles which had guided me and which I have always endeavoured to inculcate into the young men placed under me.

I have on numerous occasions taken advantage of the hospitality of the *Génie Civil* to expose certain of these principles, and there is therefore no need to go over them again : I will limit myself consequently to pointing out that when describing in 1918 a « Process for eliminating the defects due to piping and segregation in ingots of steel and other metals », I recommended that the ingot should be split, not at right angles to, but parallel with, its axis. This made it possible to follow the form of the piping and consequently to reduce the proportion of sound metal removed in the discard : at the same time the peripherical regions can be separated from the central parts, and in this way a much more homogeneous metal prepared than by the ordinary methods.

The figures reproduced below illustrate this idea. Figure 8 shews an ingot in which the shape of the pipe is shewn by a dotted line : the cross hatching shews to what the discard from the top of the ingot can be reduced when this latter is cut up by rolling into a certain number of longitudinal sections.

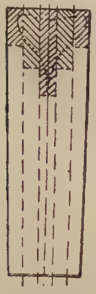


Fig. 8.

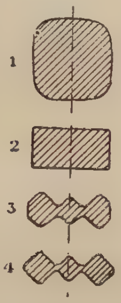


Fig. 9.

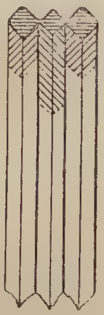


Fig. 10.

Figures 9 and 10 shew a particular application of this principle shewing the division of an ingot into three bars. The ingot of square section is first of all flattened on one side, then passed through the rolls which gradually separate it into three longitudinal bars which can be indifferently of equal or unequal section : the whole of figure 10 shews the approximate shapes required to get a centre bar smaller than the outer bars.

This centre bar includes the whole of the parts of the ingot affected by segregation : not only can the discard be made heavier, but the bar, if need be, may be reserved for work not requiring a metal of the highest quality. This division of the ingot into parts of different qualities was the particular feature I had more especially in view, and of which I have been able to make various applications. The segregation being absolutely unavoidable, it will be realised that in those cases in which it is thought to be really harmfull we can with advantage have recourse to the expensive method of completely removing the central part.

I have pointed out, however, that in many cases a real improvement would be obtained if we were content to bring the segregated parts of the ingot into a position in which its effects would be less marked than in the central region, for example, by separating the ingot into two pieces only by a symmetrical rolling. I quoted in particular the case of rails and recommended the rolling should be controlled in such a way as to bring the axial part into the region of the rail foot where any ultimate defects would be brought into view, and consequently could readily be eliminated. I must congratulate myself that this prediction should have been experimentally verified at length by the work of M. Courthéoux, which has at the same time shewn, as I did, how easily this method of rolling can be realised in practice.

In the case of rails, which occupy with reason the attention of engineers, we can then hope that the use of this method of working will make it easier to get a metal really sound. I think it useful to add that the improvement expected in this direction does not oppose in any way that looked for as well by the use of heat treatment : it ought on the contrary to increase its efficiency. It appears to be incontestable in fact that, to get from the metal everything it can give, it must be given a definite heat treatment which need not be complicated, but which in practice involves some cost. It would obviously be of little value to take such precautions without combining them with measures capable of completely removing local abnormalities in the composition of the metal, the presence of which would annul the useful effect of the treatment.

I remain, etc.,

G. Charpy,
Member of the Academy of Sciences.

[625 .17 (.42), 656 .212.5 (.42) & 728 .33 (.42)]

Reconstruction of a large railway engineering depot.

Figs. 1 to 9, pp. 560 to 567.

(From *The Railway Engineer*.)

With the progress of time, and in the course of development of a large railway system, the need for the reorganisation of yards, track lay-outs, and depots from time to time arises, and a considerable proportion of a railway company's new works' expenditure is devoted to improvements of this description. A noteworthy example of the kind of thing to which we refer is to be found in the case of the Southern Railway Company's large depot at Exeter, at which the maintenance operations connected with the Western Division of the system are centralised.

The Western Division of the Southern Railway comprises the whole of the area west of Salisbury so far as the Operating Department is concerned, and the whole of the area west of Templecombe so far as the Engineering Department is concerned. Exeter is therefore the centre, for maintenance purposes, of a section of the railway with a geographical mileage of some 400 miles and a single-line mileage of nearly 600 miles. The depot is situated about one mile east of Exeter Queen Street station, alongside the main line, at the point where the Exmouth branch joins it, and it is consequently known as the Exmouth Junction Depot.

In the early days, 50 or so years ago, small shops were in existence for the carrying out of engineering and signal work, also carriage and wagon repairs. In 1880 an engine shed, with accommodation for 40 engines, was built, and in 1902 a stores department was inaugurated, and in 1913 a concrete section of the Engineering Department was started.

The necessity for the reconstruction of the 1880 engine shed became insistent after the Armistice, and as the work of all the other departments and sections accommodated in the yard had increased beyond the capacity of their respective accommodation, the opportunity was taken of entirely remodelling the depot and to utilise the available area (approximately 28 acres) in the most efficient manner possible. When the new scheme is completed the depot will comprise an up-to-date locomotive running depot and repair shops, carriage and wagon repair shops, engineering shops, including a signal and telegraph section, a depot for the manufacture of concrete articles, a stores section, and a marshalling yard for freight train traffic.

Marshalling yard.

This yard comprises 10 parallel sidings directly connected with the main line and provided with two shunting necks, one of which serves as the up goods reception and down goods departure roads, while the other is entirely independent of the incoming and outgoing roads; the latter, however, was the only one in use at the time of our visit. The sidings are used as a concentration and marshalling yard for the bulk of the Southern Railway western divisional freight traffic, as, with a few exceptions, all freight services passing through Exeter are dealt with in the Exmouth Junction yard.

Trains from the London direction are broken up and new trains formed for despatch to Plymouth, North Devon, North Cornwall and Exmouth, also for transfer to the Great Western system at St. Davids. Conversely, wagons arriving at Exeter by up trains from these various points are assembled and formed into trains for Yeovil Junction, Templecombe, Salisbury and London. There are no public facilities for loading and unloading at Exmouth Junction, and all local freight traffic is dealt with in the goods depot adjoining Queen Street passenger station. On the average, some 700 wagons are dealt with daily at Exmouth Junction.

Locomotive running shed.

The new engine shed, which is located at the extreme eastern end of the depot, has been constructed entirely of ferro-concrete. It consists of 13 bays, each 270 feet long, and each bay is provided with a pit throughout its length. The roofing of the thirteenth bay on the north side has been specially raised in order to accommodate an overhead travelling gantry crane, capable of lifting loads up to about 63 tons, and all repairs involving lifting are carried out in this bay. The crane, which was supplied by Herbert Morris Limited, of Loughborough, is electrically operated.

On the north side of road No. 13 are the offices and shops, the latter comprising a fully-equipped fitters' shop, machine shop, smiths' shop and store. Slotting, shaping, planing and drilling machines are installed, also an axle-box lathe and four lathes for dealing with other classes of work. In addition, there are a tube cutter, a power hacksaw, grindstone, and emery wheels, together with a hydraulic press for dealing with coupling rod bushes. In the store a wall crane having a radius of 12 feet has been provided. The various machines derive their power from two lines of shafting which, in their turn, are driven by a 30-H.P. electric motor.

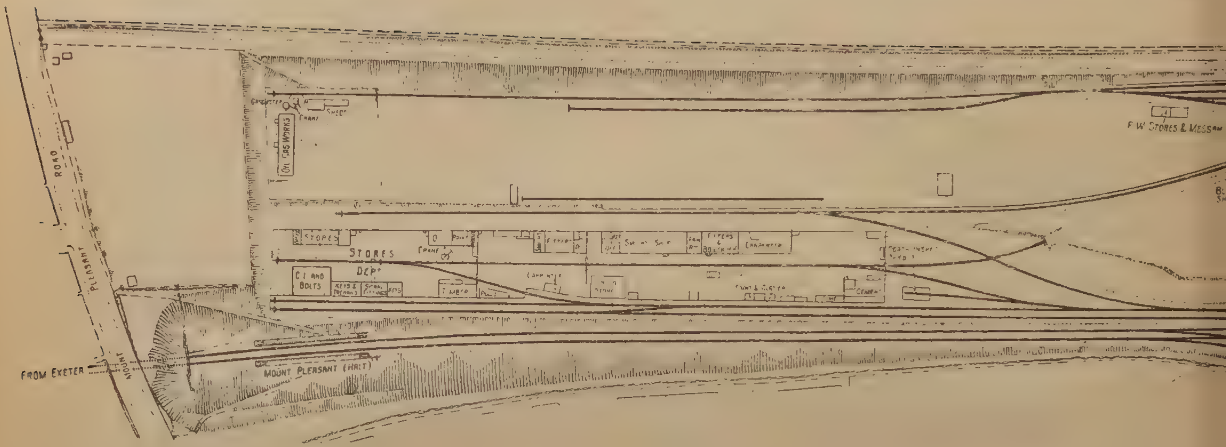
At the eastern end of the lifting road is the wheel lathe, which is independently driven by a 20-H.P. motor. The above plant, and, indeed, the whole section of the depot devoted to locomotive work, is incorporated in the Chief Mechanical Engineer's Department.

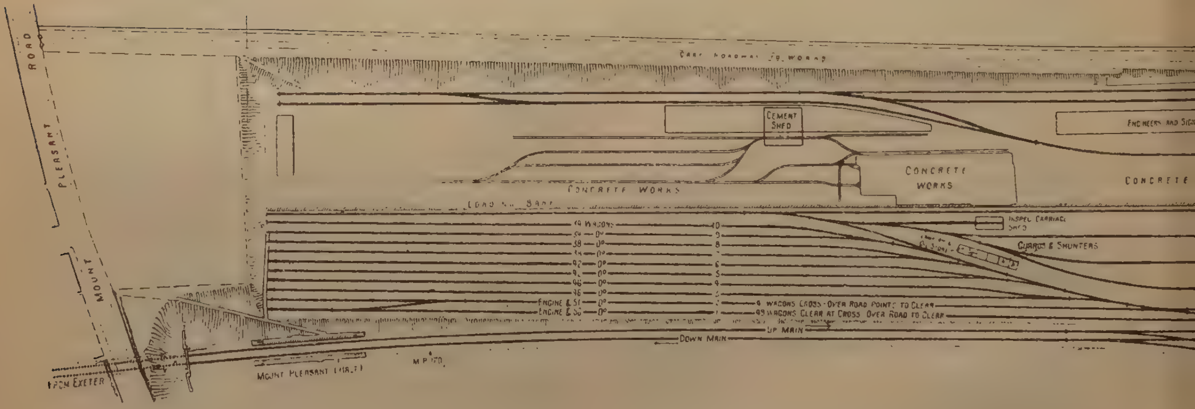
The roof of the running shed is of the saw-tooth type, the ridges of the individual bays running north and south; the easterly slopes are glazed, and the westerly slopes formed of concrete panels covered with asphalte. Excellent diffused light therefore, is obtained during the daytime. An interesting feature is the smoke hoppers, which run from end to end of the shed over each track excepting the lifting bay, and are constructed entirely of reinforced concrete. They are provided with special channels along the inside of the bottom edges to collect any moisture condensing on the inside, and such collected moisture is discharged at intervals by means of gargoyles clear of the tracks.

The roof is supported on concrete columns measuring 12 by 12 inches and approximately 18 feet high. The base of each column is carried on a specially designed concrete raft in order to distribute the load to the extent necessitated by the fact that the whole shed stands on made-up embankment formed some 50 or 60 years ago. The floor is paved with brindle bricks laid on concrete, and each of the longitudinal pits in the engine shed is carried on a concrete raft of similar design to that used for the column bases. The contractors for the construction of the shed were A. Jackaman & Son Ltd., of Slough. Electric lighting is provided throughout.

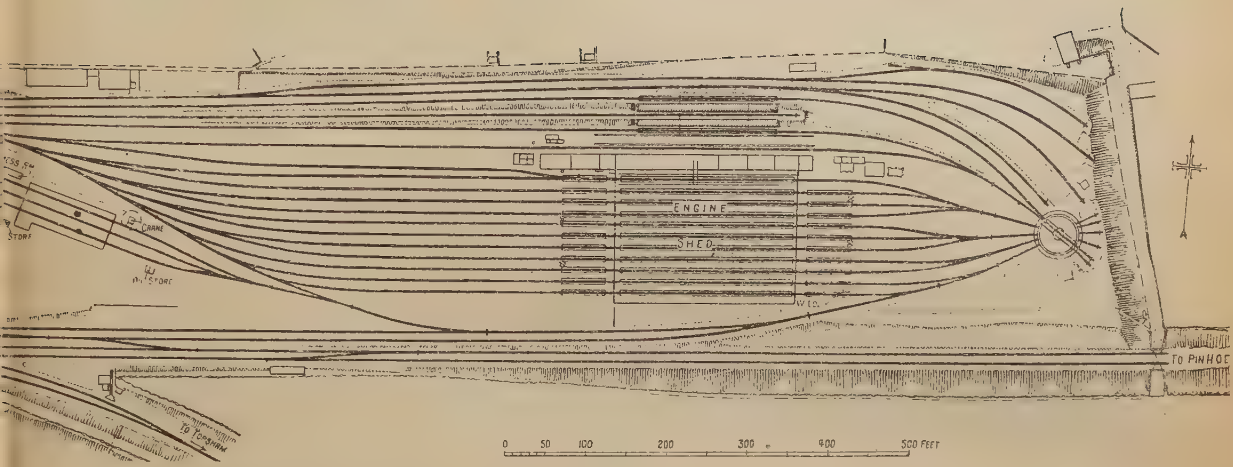
All water collecting in the engine pits as a result of engine washing is passed through a special purifying plant before discharge into an adjoining culvert. In this plant the water is freed from solid matter, whether floating or in suspension, and also from oil.

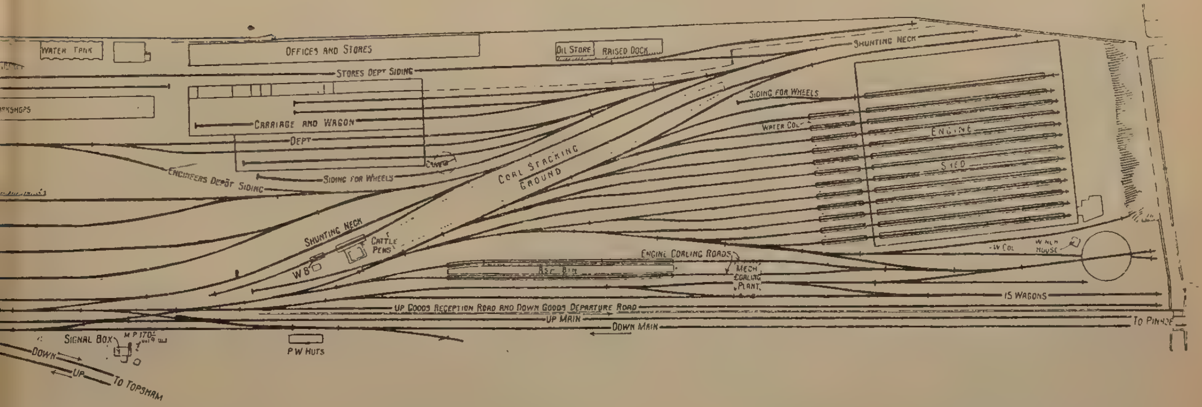
Original lay-out of tracks, engi





New lay-out of tracks, locomotive depot, engineer d, and other departmental buildings.





ps, concrete works, and wagon marshalling yard.

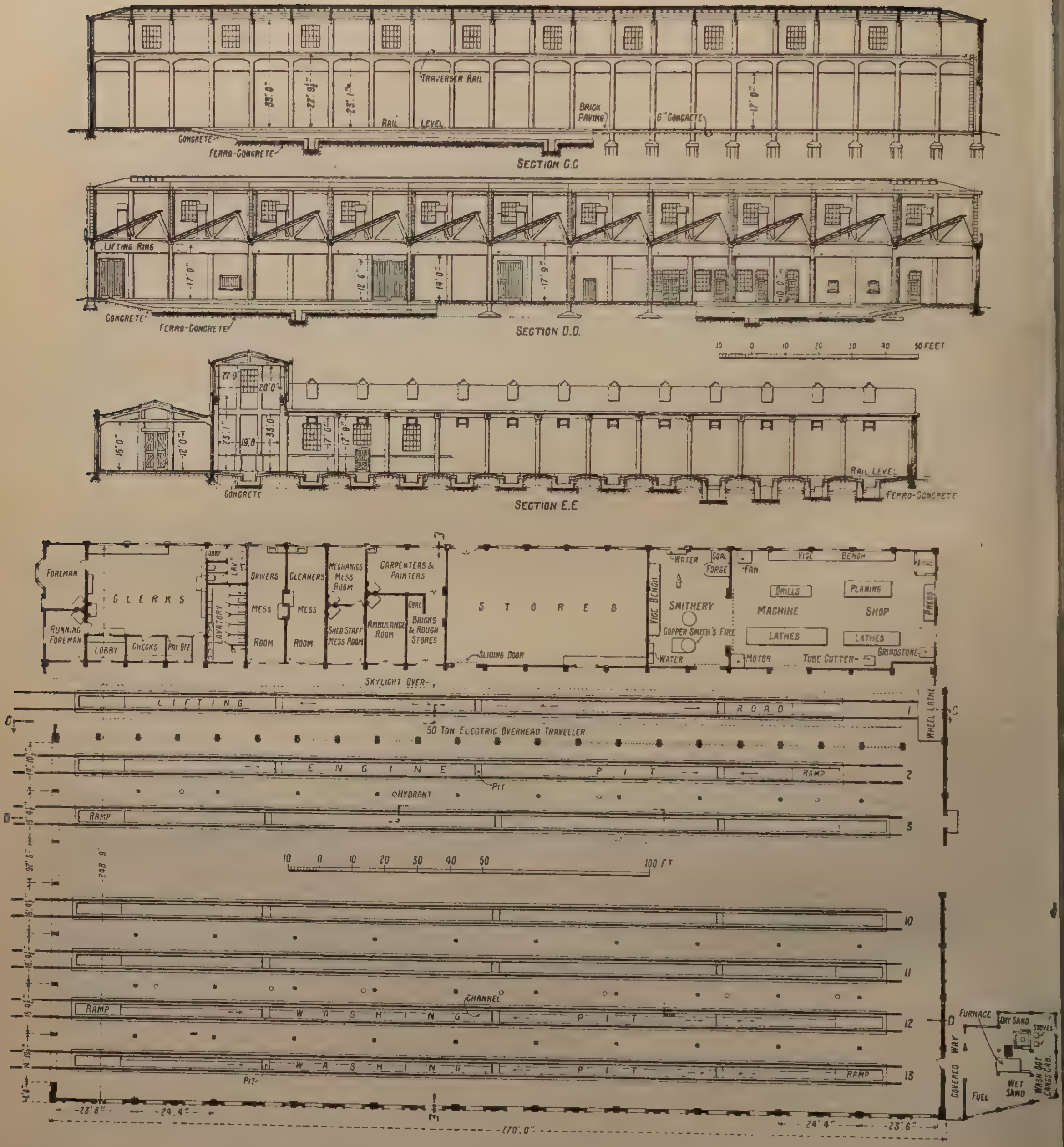


Fig. 2. — Details of new engine shed at Exmouth Junction.

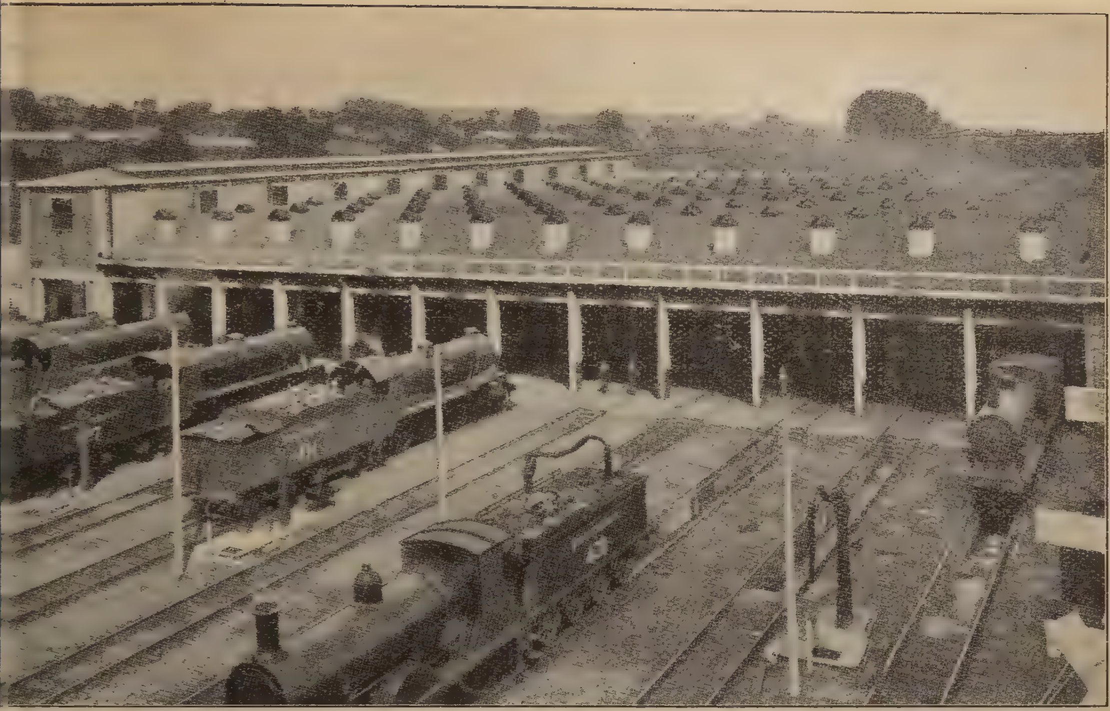


Fig. 3. — Exterior view of engine shed, showing north light roofing and lifting bay.

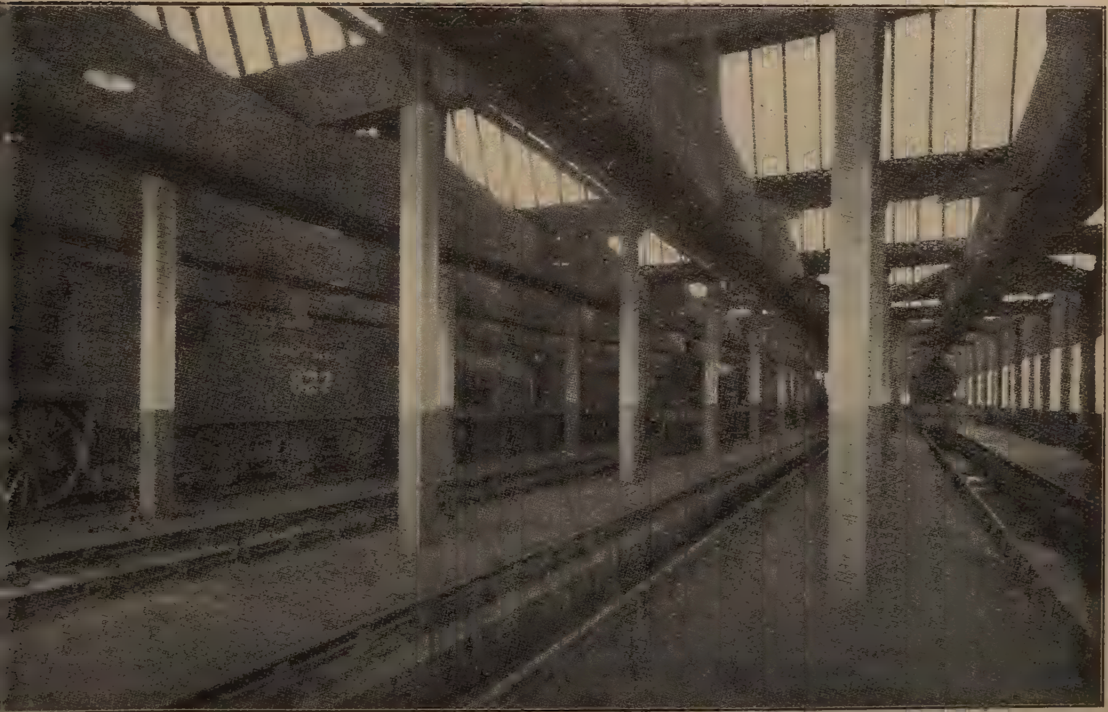


Fig. 4. — Interior of locomotive running shed at Exmouth Junction, Southern Railway.

Engine turning and coaling.

An electrically-operated 65-foot turntable is located at the south-eastern corner of the locomotive yard.

A mechanical coaling plant constructed by the Mitchell Conveyor Company, in ferro-concrete, was nearly completed at the time of our visit. This plant is located near the south-west corner of the running shed. The wagon hoist and other machinery for operating the plant will be electrically driven.

The bunker will accommodate 300 tons of coal and two locomotives can be fuelled at one time. In addition to the coaling plant, provision has also been made for the stacking on the ground of some thousands of tons of coal to serve in case of emergency.

Locomotive yard lay-out

A special feature of the lay-out is direct access to and from the locomotive shed from the main lines. Practically all the engines entering the yard come from Exeter, similarly nearly all engines leaving the yard proceed to Exeter to pick up their trains, and a reference to the plan of the new lay-out (fig. 1) will show that the connections have been so arranged that these engine movements are absolutely direct, whereas with the old lay-out several shunts were required. Observation shows that seldom, if ever, is an engine held up when moving to and from the engine shed when going on or off duty.

Stores department

The stores building measures 450 feet in length by 30 feet in width, its average height being about 15 feet. The building is located on the extreme north side of the yard and served by an independent siding connected to the eastern end of the shunting neck. The main building comprises a general store, a steel and iron store and a timber store. It is constructed in concrete block work roofed with asbestos sheeting carried on steel trusses, and the flooring is of concrete.

Side windows of large area are provided, also a series of skylights, and after dark electric lighting is available.

Specially designed racks are provided in the general store for holding the various articles. A separate building placed at a distance from the main structure is used as an oil and paint store. The whole section presents a clean and well-ordered appearance both externally and internally.

Carriage and wagon shops.

The new carriage and wagon shops are located opposite and parallel to the stores. The building, which is in course of construction, has been planned in two bays, one measuring 350 feet long by 51 ft. 6 in. wide and the other 300 feet long by 51 ft. 6 in. wide. Here again ferro-concrete construction is being employed.

The walls consist of situ-cast reinforced concrete columns with concrete block panels between them. The columns on the north side are connected by a horizontal beam about 12 feet above ground level, which will serve to carry the shafting for driving the various machines. These columns, in common with all the others, are also connected by a horizontal beam at the top which ties them all together and provides the necessary support to the guttering and finish to the wall.

The roof itself will be formed of light steel trusses covered with asbestos sheeting, continuous skylights being provided in each of the four slopes. Six roads pass into the shops, three in each bay, and one road is being provided with a pit for examination purposes. The building, when completed, will be equipped with all the necessary machinery and appliances for dealing with the running repairs to carriages and wagons arising on the Western Division. Access to it

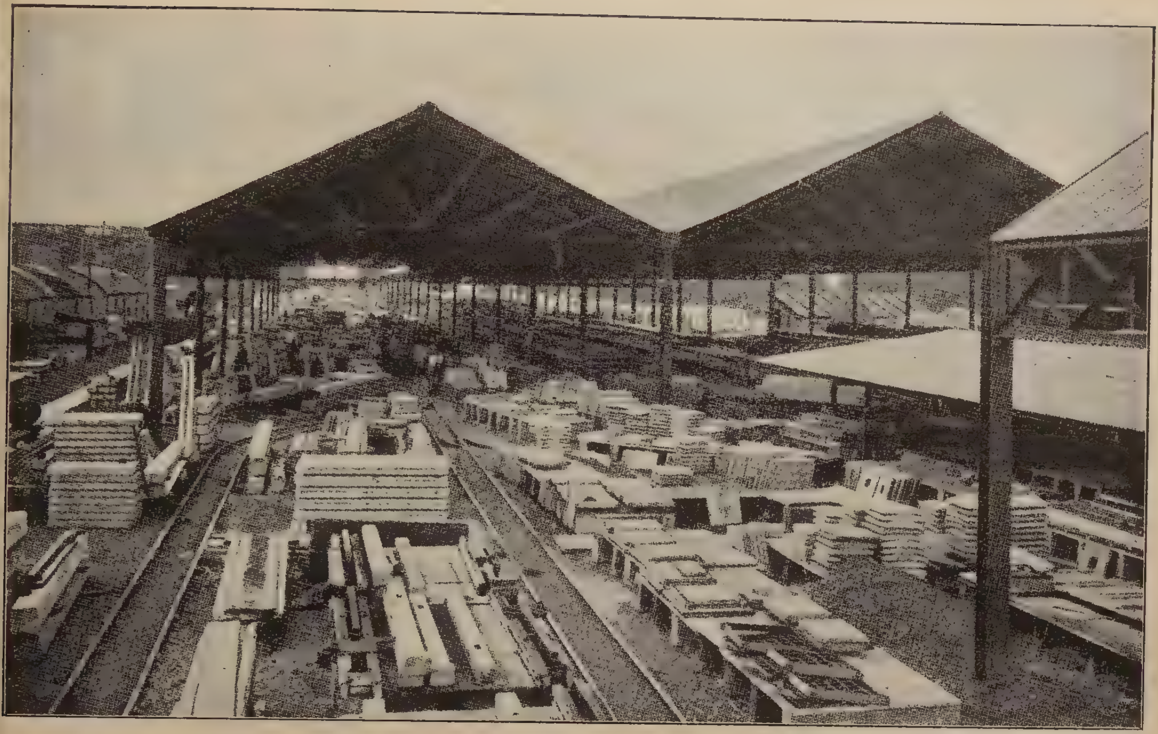


Fig. 5. — General view of concrete depot, showing new roof covering.

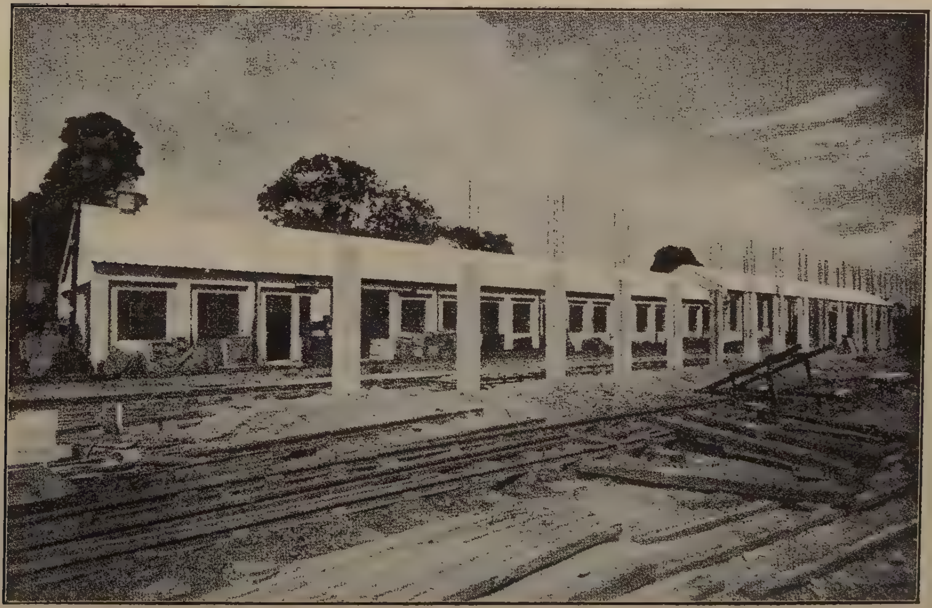


Fig. 6. — Exterior of stores building and columns of carriage and wagon depot.

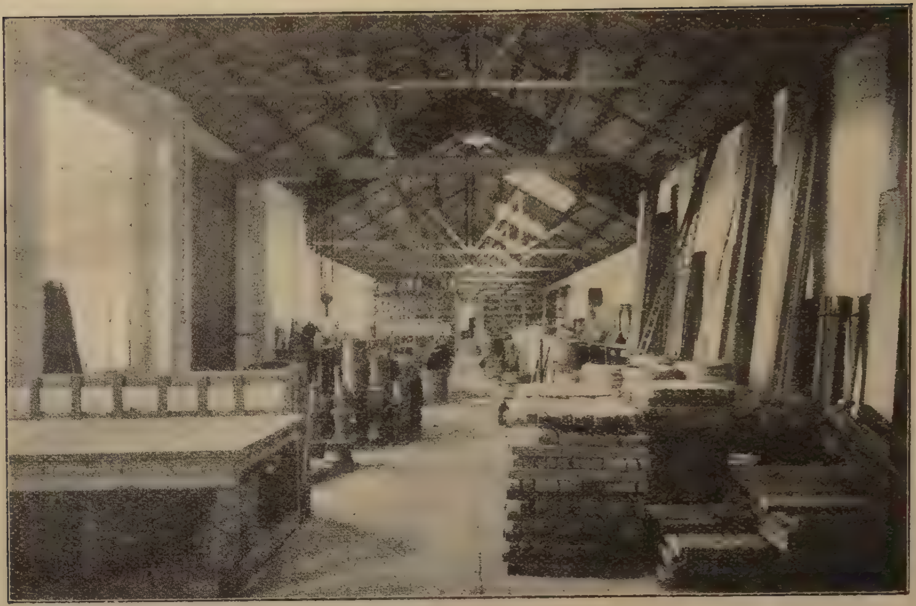


Fig. 7. — Interior of stores department.

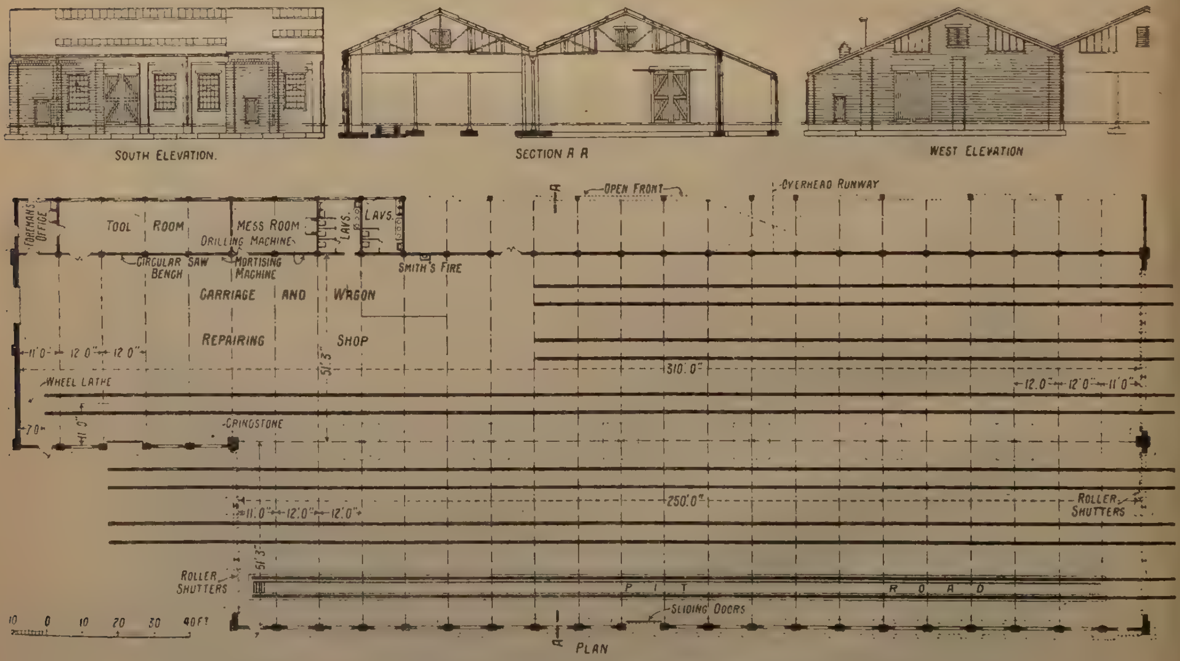


Fig. 8. — Elevation and plan of carriage and wagon shops.

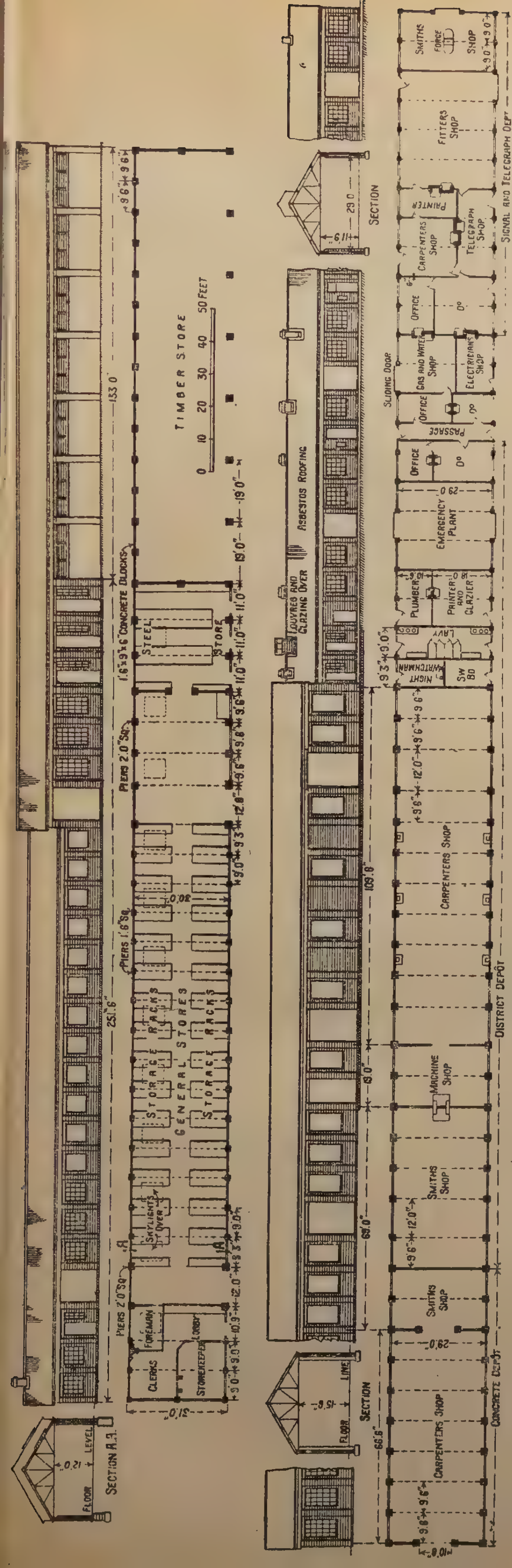


Fig. 9. — Arrangement of stores department and civil engineering shops.

will be gained from the eastern end, all six roads being connected to an independent turn-out situated on the shunting neck immediately adjoining that leading to the stores depot. Both electric light and power will be provided.

Civil engineering department.

The remainder of the ground is occupied by the Divisional Engineer's workshops and concrete depot, and the local signals and telegraphs depot. The shops form one range of concrete buildings, 500 feet in length with a width of 30 feet. The height is about the same as that of the stores buildings, namely, 15 feet. No tracks lead into these shops, but there are two sidings on the north side and a cart road and a siding on the south side.

The westernmost portion of the building is devoted to the construction of moulds used in the concrete depot, and facilities are provided for dealing with the necessary carpenters' and smiths' work. At the eastern end are located the shops and offices of the signals and telegraphs section, while in the centre are the general building depot shops, which include carpenters', smiths', machinists', plumbers' and painters', together with the necessary offices for the various inspectors and foremen.

The shops are being equipped with up-to-date electrically-driven machinery, and so far as possible, each machine is provided with a separate motor.

The area of ground devoted to the manufacture of concrete articles is 175 feet wide and over 1 000 feet in length, and a considerable portion is roofed over. As will be seen from the lay-out plan, this area is served by sidings situated on either side of it. The northernmost sidings are some four or five feet higher than that on the southern side, and full advantage of this difference in level is taken, as the northernmost sidings are used for all incoming material, such as stone chippings, sand and cement for concrete and steel for reinforcement, and the southernmost siding for the despatch of all manufactured articles. Cement is unloaded direct from wagons into a cement shed situated in the centre of a long dock adjoining one of the two northern sidings, and chippings and sand are unloaded from the wagons on to the dock on the left and right of the cement shed respectively, with the assistance of a steam crane and grab.

The concrete mixer is situated on the ground on the south side of the dock, immediately opposite the cement store, and owing to the difference in level, it has been possible to arrange for the hopper of the mixer to be flush with the floor of the shed; and, with sand and chippings on either side, all the constituents necessary for the preparation of concrete can, therefore, be barrowed direct to the hopper of the mixer. The mixed concrete is distributed over the yard by means of trolleys running on a 2-foot gauge track. The products of the depot consist of large quantities of platform coping slabs, platform walling brackets and slabbing, fence posts, cable posts, telegraph poles, signal posts, yard lighting poles, etc., etc.

A design for a pre-cast concrete footbridge was developed some time ago, and ever since there has been a steady demand for structures of this nature. At the time of our visit the girders for a concrete footbridge 300 feet long, consisting of no less than 8 spans, were in course of construction. The most recent development is the design of a sectional concrete building which can be utilised for a variety of purposes. A particular feature of the design is that the building can be taken down and re-erected at any time, and that it can also be extended by the addition of new sections if and when required.

Electric power and lighting.

The current for the power and lighting is obtained from the Exeter City Corporation. The supply, which is 50-period alternating current, enters a transformer house situated on the company's property at 2 000 volts, and is there transformed down to 600 volts for power purposes and 200 volts for lighting purposes.

These supplies are distributed throughout the yard by means of overhead cables carried on specially-constructed poles. The most interesting of these poles are the specially-designed towers which carry the cables across the running lines. Each pole is in the form of a triangular tower. Each of the three sides of these towers consists of a single pre-cast braced girder, and the three sides are held together by special steel bands at the corners and also by the series of channel irons at the top carrying the insulators and wires. The feet of the towers are securely anchored into specially-designed reinforced concrete rafts, which are of such size and weight as to obviate the use of all guys.

The remaining poles are of duplex type and are more or less orthodox in design. Separate cables are run from the transformer house to the locomotive running shed, the coaling plant, the carriage and wagon shops and the engineer's workshops, and a special switchboard is being provided to control the power distributed in the engineer's shops.

[621 .335 (.54)]

Electric express passenger locomotive for the Great Indian Peninsula Railway.

Figs. 1 to 5, pp. 570 and 572.

(From *Engineering.*)

For working the express passenger service on the main line of the Great Indian Peninsula Railway, on which the minimum radius of the curves is 500 feet, and the maximum gradient 2.7 %, an experimental locomotive has been ordered through Messrs. Merz and McLellan from each of three different contractors, *viz.*, Messrs. British Brown-Boveri, Limited, Trafalgar House, Waterloo-place, S. W. 1, Messrs. The General Electric Company Limited, Magnet House, Kingsway, W. C. 2., and Messrs. Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester. This article refers to the one ordered from Messrs. British Brown-Boveri, Limited, which has just been completed and tested. It has been constructed to run on the 5-ft. 6 in. gauge track and under a normal pressure on the overhead conductors of 1 500 volts continuous current.

A longitudinal section of the engine is given in figure 1, and from this it will be seen that it is of the 4-6-4 type. The three driving axles, however, are not coupled in any way, each incorporating the Brown-Boveri individual axle drive, to which we shall refer again later. The bogies are of the maker's self-centring type, with brakes acting on all four wheels, as shown. There are six main motors, two driving each axle and these can be connected in series, in series-parallel, or in parallel for starting and speed regulation. In no case, however, does the voltage applied to any individual motor exceed half the line voltage, since with what are described as parallel connections, the two motors in each group are actually connected in series. Including weakened-field positions nine economical speeds are obtainable, as will be explained later, and the engine can be run at any of these speeds continuously. The principal data relating to the locomotive are as follows :

Total length over buffers	56 ft. 2 1/4 in
Rigid wheel base	15 feet.
Bogie wheel base.	9 feet.
Diameter of driving wheels.	5 ft. 9 in.
Diameter of bogie wheels	3 feet.
Weight of mechanical portion, including drives . . .	68 000 kgr. (66.9 tons).
Weight of six motors	24 000 kgr. (23.6 tons).
Weight of two current collectors	1 100 kgr. (1.1 tons).
Weight of apparatus and miscellaneous equipment . .	11 400 kgr. (11.2 tons).
Total weight	104 500 kgr. (102.8 tons)
Adhesive weight	60 000 kgr. (59 tons).
Total H. P. at motor shafts (continuous rating) . . .	1 890 H. P.

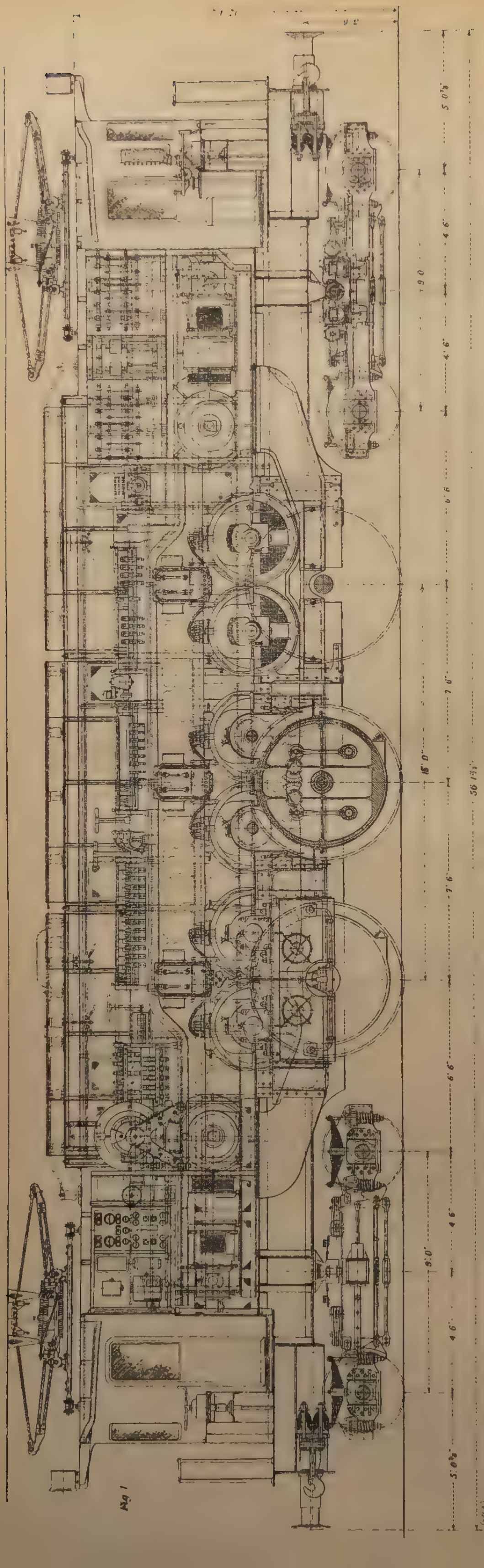


Fig. 1. — 4-6-4 electric express passenger locomotive for the Great Indian Peninsula Railway.

The motors, one of which is illustrated in figure 2, are of the six-pole type, series wound, with interpoles, and are each capable of developing 315 H.P. at 615 revolutions per minute continuously, with 1 400 volts applied across the terminals of a pair, the current then being 360 amperes; on a one-hour rating, the power developed is 405 H. P. at 560 revolutions per minute, the current being 460 amperes. Air for cooling the motors is supplied by two electrically-driven blowers, located as shown in figure 1, the air being delivered through sheet-metal trunks to the opening shown at the bottom of the casing on the right of figure 2, and leaving through openings covered with perforated metal at the commutator end. Fans are also mounted on the armature shafts for cooling purposes, and these provide sufficient ventilation for slow-speed and intermitient running. It is possible to use only one of the electrically-driven blowers if desired, the inlet opening of the other blower then being covered.

As previously stated, a pair of motors is coupled to each driving axle by means of the Brown-Boveri individual-axle drive, which is employed on the Swiss Federal Railways as the standard for high-speed running. The drive is partly shown on the central driving wheel in figure 1, but perhaps more clearly in figure 5. A pinion incorporating a spring coupling, the inner member of which is shown in position on the left of figure 2, is mounted on the end of each armature shaft, the two pinions of a pair of motors engaging with a single gear wheel outside the driving wheels on one side of the locomotive and supported from the main frame of the latter; the gear ratio is 1 : 3.237. Referring to figure 5, it will be seen that pivoted on the outer face of the gear wheel are two short-toothed segments, the inner ends of which are in engagement as shown. To the outer ends of the toothed segments are fitted links working in ball-and-socket joints.

These links are connected to ball-ended crankpins on the driving wheels, the crankpins passing through holes in the gear wheel which are sufficiently large to give ample clearance. It will be understood that, with the arrangement described, a uniform torque, equally divided between the two links, is transmitted from the gear wheel to the driving wheels, although a certain amount of vertical and lateral movement is permitted between them. The engagement between the pinions and the gear wheel is, of course, unaffected by the movement between the gear wheel and the driving wheels.

The whole of the gearing is normally enclosed in an oil-tight casing, built up of rolled sections, plates and steel castings; a leather sleeve, of concertina form, is fitted around the crankpins between the gear wheel and the driving wheel to exclude water and dirt. Oil filled into the bottom of the casing is carried up by the gear teeth, and, being thrown by centrifugal force on to the casing, some is caught in one or other of the two reservoirs shown on each side of the central gear wheel in figure 1; the reservoirs can, however, be filled independently if necessary. From the reservoirs, oil is drawn through filters, by a small duplex pump, driven from the main gear wheel as shown to the left in figure 1, and delivered to the main gear-wheel bearing, and thence, through suitable passages and channels, to the bearings and teeth of the toothed segments, and also to the ball and socket bearings at both ends of the links. The pinions and the motor-shaft bearings also receive a supply of lubricating oil from one part of the duplex pump, the pipes for this purpose being visible in figure 1. Several important advantages, which cannot be fully dealt with here, are claimed for the individual-axle drive described above, but among them we may mention the smooth running of the locomotive, reduction in the wear of gearing, tyres and track, efficient lubrication combined with low oil consumption, and easy accessibility of all parts requiring inspection.

A photographic illustration of one of the pantographs, in the elevated position, is given in figure 3, and both are shown, in the depressed position, in figure 1. They are of the double-bow pattern, as shown, and are raised and lowered by a compressed-air cylinder, which can be distinguished between the springs in figure 3. The height of the overhead conductor varies from a maximum of 20 ft. 6 in. to a minimum of 14 ft. 10 in., so that the working range required for the pantograph is 5 ft. 8 in. From the pantograph, the current is led through isolating switches, which can be operated by handles inside the body, to a special form of high-speed circuit breaker, shown in position in figure 1, immediately above the blower on the left of the illustration. There are actually two circuit breakers connected electrically in parallel, and coupled mechanically so that one is opened a fraction of a second before the other. When the first breaker opens, it puts a resistance in series with the second breaker and so reduces the current to be interrupted by the latter. In both cases the contacts are only separated for a comparatively short distance, of the order of 1/2 inch, but a very powerful magnetic blow-out is provided to draw out the arc between circular arc shields. Staggered radial ribs are provided on the opposing faces of the arc shields, and these have a further attenuating effect on the arc. The circuit breaker is tripped by no-voltage and overload relays.

A photograph of a part of the main controller is reproduced in figure 4. This controller, and another exactly similar part, neither of which is shown in figure 1, are located at the opposite ends of the engine, and are used for cutting out the resistance in the armature circuit and also for weakening the fields; each part deals with three motors. Of the

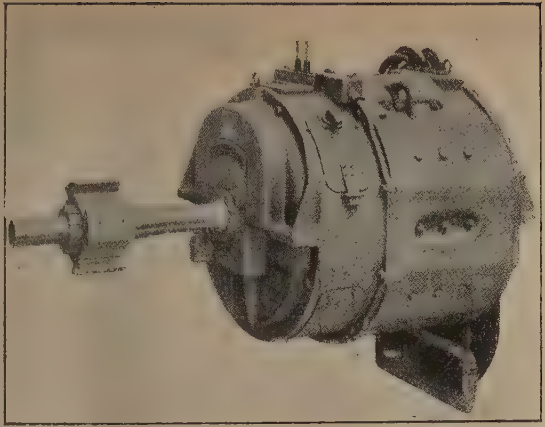


Fig. 2. — One of the main motors.

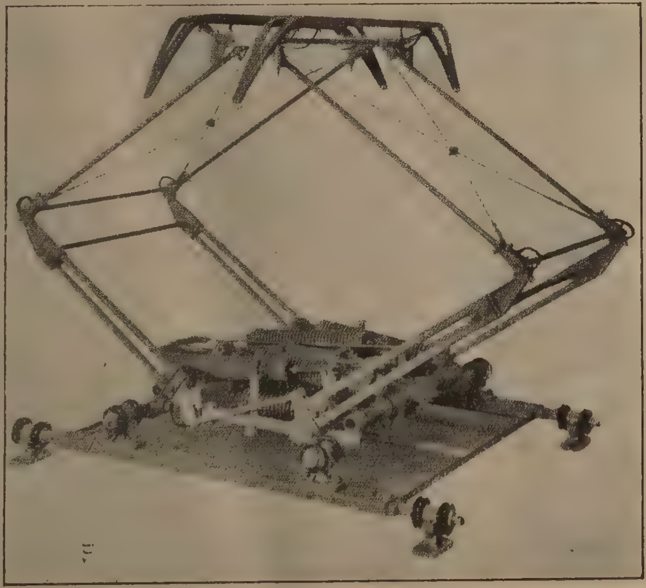


Fig. 3.
Pantograph current collector.

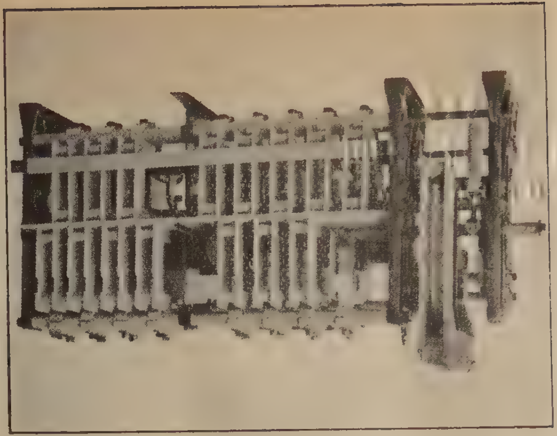


Fig. 4. — Part of main controller.

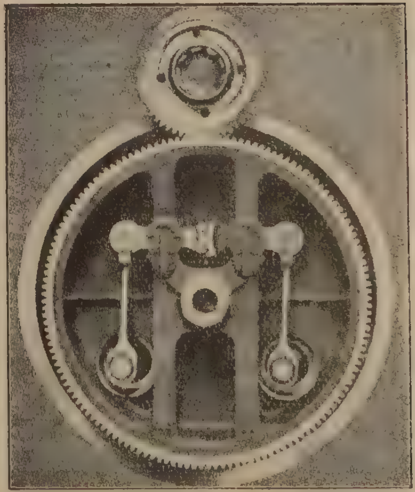


Fig. 5. — Pinion and gear wheel
of the Brown-Boveri individual-axle drive.

controllers visible in figure 1, that on the left, near the circuit breaker, is employed for making the series, series-parallel, and parallel connections, while the next to the right, is provided to enable one or more motors to be entirely disconnected if they should become damaged. The two other controllers shown are used for altering the connections to the motors for reversing the direction of rotation. The whole of the controllers are operated electro-pneumatically from a master controller, one of which is provided in a cab at ach end of the engine. Movement of the controller handle, and of a separate handle controlling the combination switch, which will be referred to again later, operates the electrically-controlled valves of compressed-air servomotors which rotate the shafts of the controllers and make and break the contacts as required.

The slowest speed is, of course, obtained with all six motors in series, and with the whole of the resistance in circuit. To increase the speed, the resistance is cut out in 13 steps by the controllers, one of which is shown in figure 4, and when this has been done, the master controller handle is returned to any one of the first four positions and the connections altered to series- parallel by a separate handle controlling the combination switch. With these connections, three motors are in series and the two groups of three in parallel. The resistance is then cut out in steps until it has all been removed, when the controller handle is returned to any one of the first six positions, the connections then being altered by the combination switch to connect three groups of two motors in parallel, the two motors in each group being in series. When the resistance has all been cut out, the speed can be still further increased by weakening the fields, and two positions on the master controller are provided for this purpose. The field could, of course, be weakened with the series and series-parallel connections, and by this means. the nine economical speeds above referred to can be obtained. It may here be mentioned that the first movement of the master-controller handle from the off-position, switches in the low-voltage circuit for actuating the relays controlling the valves of the compressed-air servomotors, by which the main controllers are operated. Signal lamps are provided to show when current is on the main and relay circuits. The handle controlling the combination switch has three positions : Series, series-parallel and parallel in both forward and reverse directions of running, giving six positions in all, and this handle is so interlocked with the controller handle that it is not possible to change from one type of connections to another unless a suitable amount of resistance is included in the armature circuits. In general, the movements are all interlocked to prevent damage by improper use, and it is also noteworthy that in changing the connections the motors are never entirely open-circuited.

Although they are not shown in the drawing from which figure 1 has been reproduced, brakes are, of course, fitted on all the driving wheels, as well as on the bogie wheels. These brakes are operated by compressed-air, and two electrically-driven compressors are provided to supply the air for this purpose, as well as for operating the pantograph and the servo-motors for the controller gear. A hand brake is also fitted on the engine, but regenerative electric braking is not provided for. Vacuum brakes are used on the train, and electrically-driven pumps are installed to produce the necessary vacuum. It may be of interest to mention in this connection that a proportional valve is fitted between the air and vacuum brakes, so that an application of the vacuum brake on the train automatically applies the air brake on the locomotive to the same extent. Other auxiliaries fitted include the two blowers, already mentioned, for ventilating the motors and a single motor-generator set producing current at 50 volts, for lighting, operating the relays, etc. A small battery is also installed for supplying 50-volt current in emergency, or if the main current is off. All the auxiliary motors are operated at the full line voltage and are controlled by push buttons and contactor switches. The former are mounted on the side of the driver's cab, just above the controller handle, and can be seen in this position on the right of figure 1.

The contract performance required from the locomotive was that, with current at 1 400 volts, it must be capable of exerting a tractive effort, measured at the wheel tread, of 24 000 lb. at 36 miles per hour with full field, and not less than 6 300 lb. at 70 miles per hour with weak field. The maximum speed required in service is 75 miles per hour, but the engine has been actually designed for safe running at 85 miles per hour.

Another requirement of the contract was that in starting from rest up to 36 miles per hour a trailing load of 450 tons on a 1 % gradient ten times at five-minute intervals, the temperature rise of the resistances must not exceed 210° C. (410° F.), and when starting under these conditions, the tractive effort for each pair of driving wheels must not vary by more than ± 10 % from the mean value.

[**625 .258 (.73) & 656 .259 (.73)**]

Car retarders at Mechanicville.

Figs. 1 to 6, pp. 574 to 580.

(*Railway Age.*)

The latest refinements in car retarder apparatus are now to be found at Mechanicville, N. Y., on the Boston & Maine Railroad, near the western terminus of the Fitchburg-Berkshire division of that road, where a new eastbound hump freight yard was opened on 14 January.

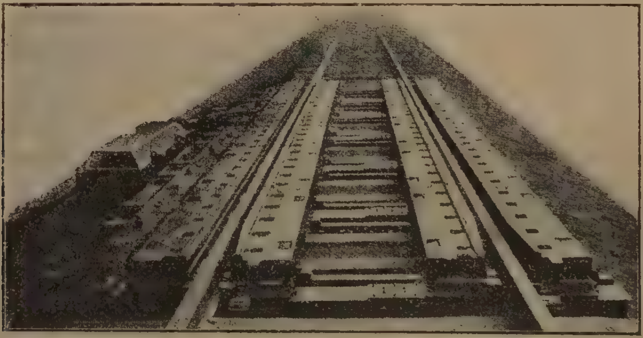


Fig. 1. — G. R. S. car retarder.

Springs covered with heavy iron casting.

The layout of this yard differs in many features, not only from the former hump layout at this place, but also from other yards previously equipped with car retarders. The principal difference is in the arrangement of ladders, whereby each group of six tracks is served by one group of retarders, the yard having 36 classification tracks. Each group of six is served by a ladder upon which there is a double retarder 80 ft. 8 in. in length, which brings the cars to their final yard speed for all of the tracks in that group. There is a thoroughfare track from the receiving yard to the outgoing end of the classification yard and from this track the stock pens, ice house, repair tracks, locomotive shop and engine terminal are served. There are also run-around tracks from both sides of the classification yard to the receiving yard to permit engines to run around the hump if more than one engine is being used, or to pull back cars that have to be reclassified. From the receiving yard to the « hump crest » the distance is about 2 300 feet, with independent leads for switching both the transfer and the repair tracks.

Description of yard.

The leading features of this yard are :

Receiving yard. . . .	10 tracks.	737 cars.
Classification yard . .	36 —	1 930 —
Transfer shed	7 —	237 —
Repair sheds.	6 —	240 —

Stock pens.
Ice house : 10 000 tons.
Engine terminal : 25 stalls.

Trains are made up on the classification tracks, and four doubling over leads are provided at the outgoing end of the yard in addition to the two ladders, each serving approximately six tracks. Practically all trains carry more than one classification, so that by assigning classifications that ordinarily go together to the same group, six trains can be made up at one time without interfering with each other. This arrangement eliminates the pulling down of cars to a departure yard and permits doubling of trains by road crews; cars can be humped closer to departure time of trains, and it allows the doubling together and caboosing of trains by the humper.

Ladder arrangement. — To obtain high switching capacity it is essential that there be a quick separation of cars on to many diverging routes, with a minimum of travel to the clearance point on each classification track; and this minimizes the difficulties incident to different rolling qualities of different types and weights of cars. The compact layout of switches and retarders at Mechanicville has been obtained, it will be seen, by a liberal use of lap switches. At the « junction switch », a lap switch 126 feet from the crest of the hump, the traffic is diverted to three routes. The group switches where each of these routes is again divided are 189 feet beyond the junction switch. The cars are thus sent over six diverging routes only 315 feet from the hump crest; and the maximum distance from the junction switch to the most distant classification-track switch is 595 feet.

The grades.

As the rate of acceleration decreases as the speed increases, and the braking power required to stop a car increases in proportion to the square of the speed, grades were carefully calculated so that cars never need move at high speeds.

Mechanicville has a natural descending grade from the entrance of the receiving yard to the outgoing end of the classification yard. The hump is simply a small knoll (about a foot above the grade of the lead) to get the slack on the pin. The hump incline drops about 2 feet in 50 feet (4 %) which separates the cars sufficiently for throwing switches conveniently between cuts. From the foot of the hump there is 75 feet of

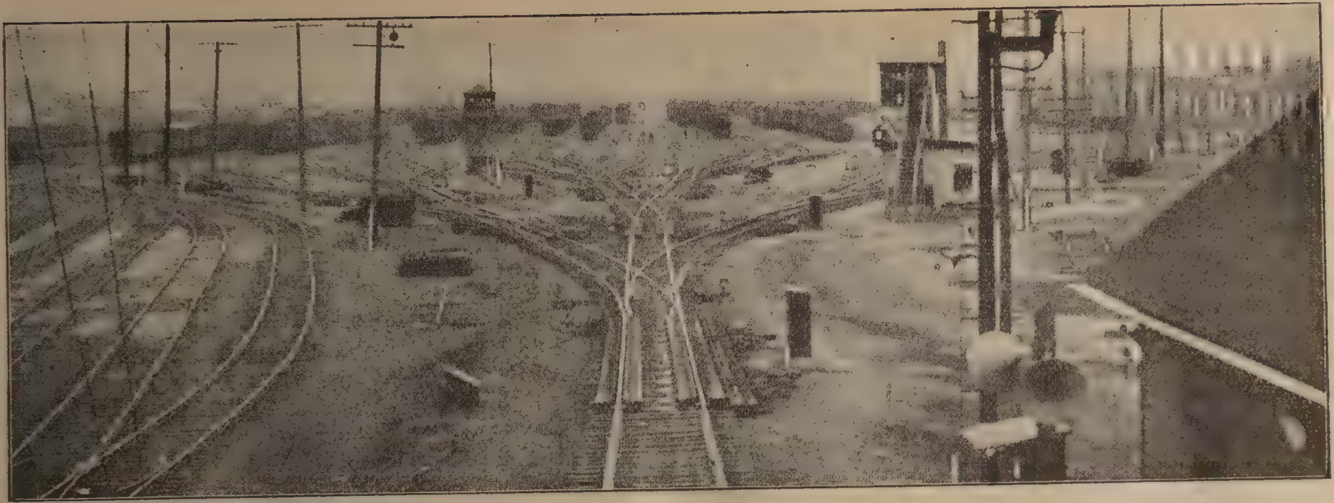


Fig. 2. — Car retarders at Mechanicville; looking east from hump.

Retarder No. 1 in the foreground. Two-story power house and tower on the right, beyond the second retarder. Tower B in left center.

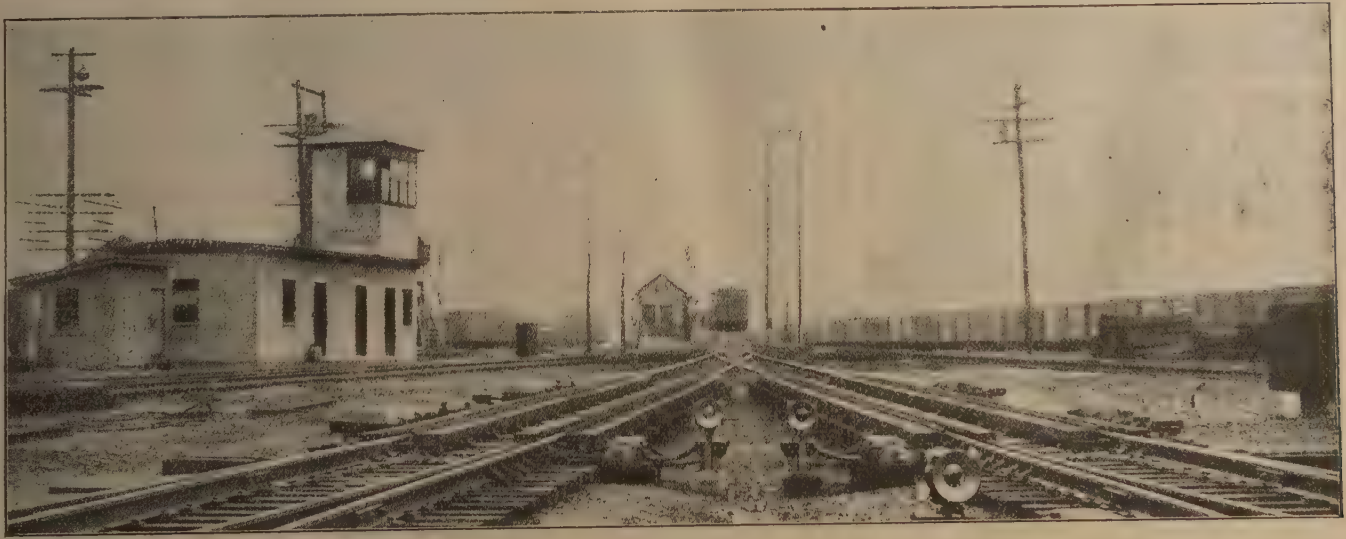


Fig. 3. — Mechanicville Yard, Boston & Maine Railroad; looking west toward hump.

Retarders No. 7 and No. 8 in foreground; power house and tower A at the left.

2 % grade to the junction switch and in this 75 feet are the two 33-foot retarder units. From the junction switch to the clearance point on each of the six group ladders there is 290 feet of 1.2 % grade, with a 40 ft. 4-in. retarder in the rear of each of the three group switches, as shown.

At the clearance point on each of the six group ladders there are two 40 ft. 4-in. retarder units on a grade of 0.8 %, which is sufficient to start the average car which might be stopped in the retarder. Here the cars are brought to proper yard speed (about 4 miles per hour) and this is the last point of retardation. From this point to the clearance point on each classification track the grade is 0.35 % while the body of the yard is 0.25 %.

These grades are sufficient to carry an empty car at a speed of about six miles an hour to the last retarder; while the incline and group ladder retarders control the speed of the heavier or easier rolling cars. All grades are compensated three 100ths per degree of curve to offset curve friction.

That the layout will constitute a fast switching machine has already been shown during its first month in service.

With the operators still new, a speed of 250 cars an hour has been reached on individual trains; and a speed of three cars a minute is normal.

Reconstruction.

The original Mechanicville yard was built in 1914 as a hump yard, and was of the conventional design, with the receiving yard in the rear of the classification yard. There was no departure yard, trains being made up on the classification tracks. The hump was high, with a long stiff incline, to give the cars high acceleration at the beginning of the ladders, with light grades through the ladders and yard. There were two ladders of the herringbone type through the center of the yard, between which was the gas car track. From the crest of the hump to the clearance point of the last classification track, the distance was 3 100 feet, and the average ride was about 2 000 feet.

Track work by company forces.

The hump was moved 1 700 feet easterly and, as previously described, the yard was divided into six groups of six tracks, each served by a group ladder. The track and grade work was done entirely by railroad forces and operations were carried on in sections to minimize interference with operation. Throughout the period of reconstruction all yard work was performed as usual and at no time were other yards called upon to relieve the Mechanicville yard. Work was started on 1 June, and on 20 August, the new hump and about two-thirds of the track changes were completed; and the entire grading and track changes were completed on 15 September.

Operation.

For about three months after the track and grade changes were completed operation was continued with « riders ». The new location of the hump, with the concentrated ladder layout and revised grades, reduced the average ride from about 2 000 to 850 feet; and as a result it was possible to keep the hump going continuously with 16 riders and two engines, where previously 35 riders, a motor car, and three engines had been necessary.

This was largely due to the shortened « ride », as the riders after bringing the car down to the proper speed at the clearance point on the classification tracks left the car and returned to the hump. This three months' operation showed that the economies to be obtained by the revised grade and ladder arrangement, amounted to about 26 % per annum on the gross cost of the changes in tracks and grades.

Car retarders.

The retarders consist of 17 units (ten locations) aggregating 577 ft. 6 in. in length, of the latest all-electric design of the General Railway Signal Compa-

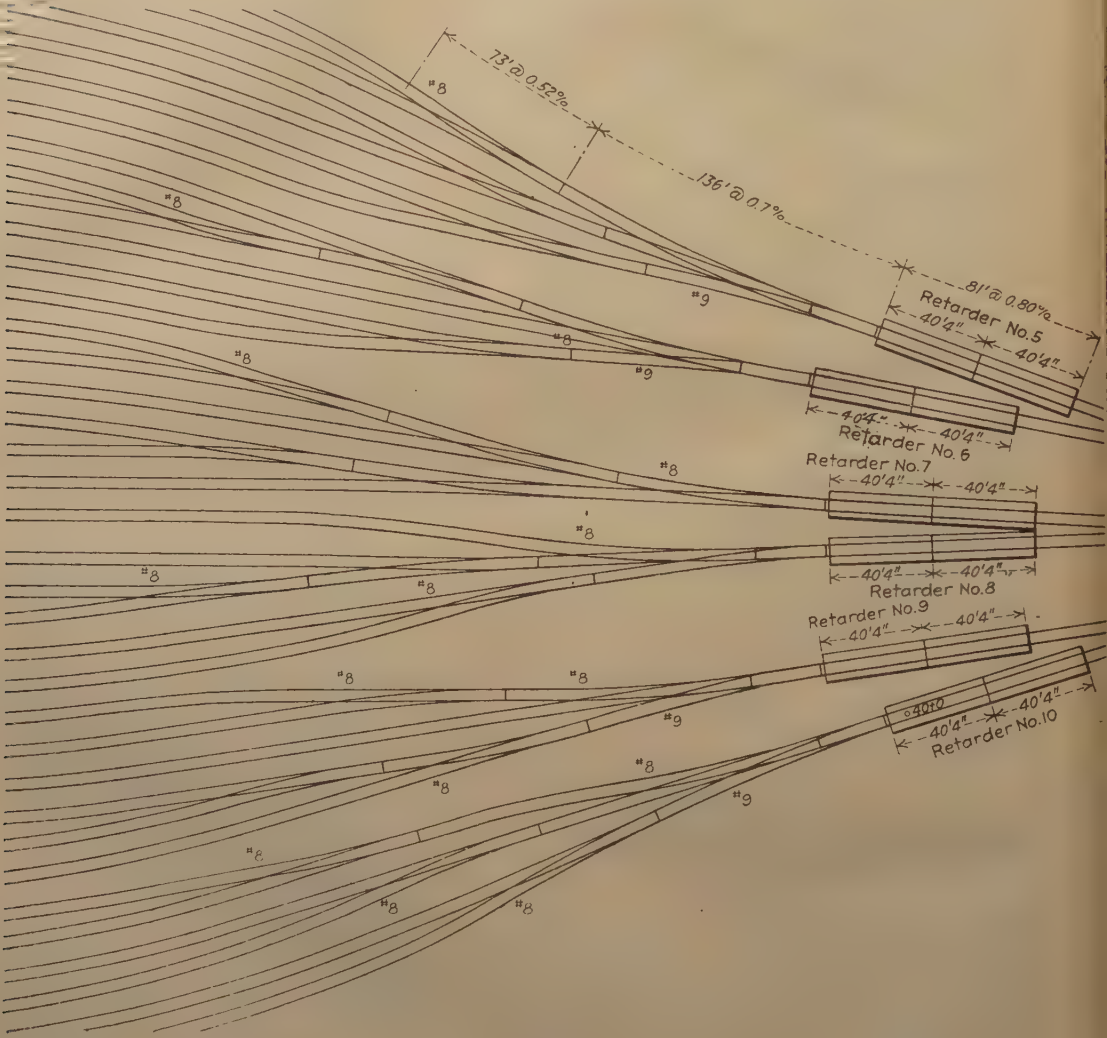


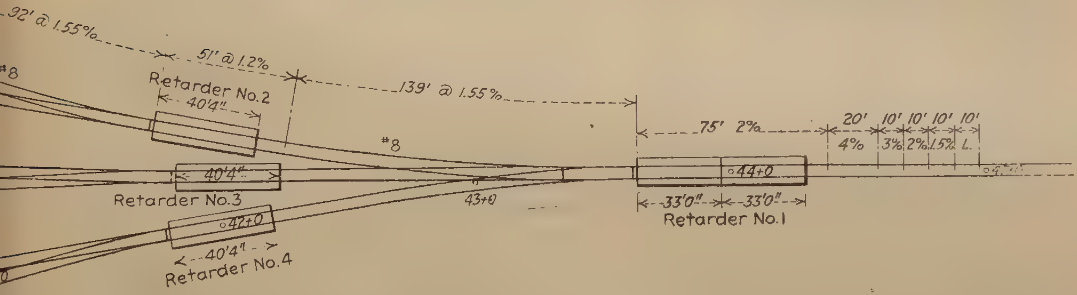
Fig. 4. — Eastbound classification yard at Mechanicville, N. Y.

Thirty six tracks, six ladders, ten sets of retarders.

ny (1) (2). These retarders are of extra heavy construction, with the springs below the rail, and protected by a heavy plate. The lever arrangement has been redesigned and strengthened. The pressure is equalized on both sides of the car wheels, the retarders on each rail acting independently. This allows for variations in wheels; and, further, if a car is lifted in the retarder by excessive pressure, it continues to roll with the flange guided by the retarders, but above the line of pressure. As a result the lifting of a car does not tend to derail it, the retarder simply holding it over the rail (see fig. 6). The shoes are made of rolled steel fastened by heat treated nickel-steel screws which are accessible from the top of the shoe beam. The parts are made of heavy steel to withstand the heavy shock of continued service. The operating pins are larger and individual lubrication is provided to minimize wear. The adjustments and maintenance have been simplified by using only one adjustment for each spring with an overall adjustment to compensate for shoe wear.

Control towers. — This layout is controlled from two towers, the junction tower A being about 360 feet from the hump crest and opposite the switches of the six group ladders. This tower is a

Fig. 4 (*continued*). — Eastbound freight classification yard at Mechanicville.



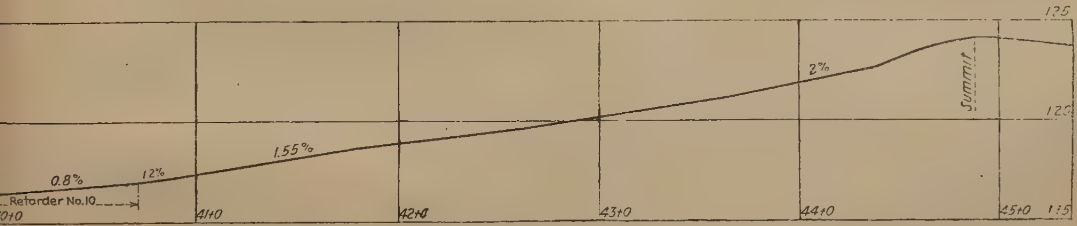


Fig. 5. — Profile from summit to retarder No. 10.

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(1) An illustrated article on the G. R. S. car retarders, as used at Blue Island, Ill., on the Indiana Harbor Belt, was printed in the *Railway Age* of 26 February, 1927, p. 570, including a description of the apparatus for lubricating journals with hot oil. The Blue Island plant was described also in the *Railway Age* of 15 November, 1924. The plant at East St. Louis, Mo., on the Illinois Central, was described in the *Ralway Age* of 6 March 1926, p. 593, with details of the skate-placing machine.

(2) See also *Bulletin of the Railway Congress*, numbers for January, 1926, p. 11, and August, 1926, p. 791.

small second-story of the power house and controls the five ladder switches, five incline retarders, and the switches and retarders on two groups of classification tracks. The second tower B is located in the field between tracks 12 and 13, and controls the switches and retarders of the other 24 classification tracks. Tower A controls nine retarder units and 15 switches; tower B controls eight units and 20 switches; total 17 units and 35 switches.

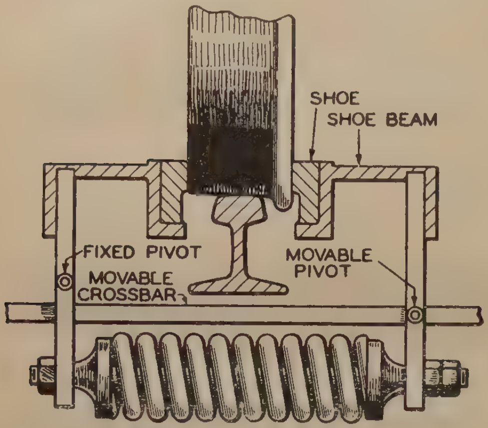


Fig. 6. — Detail of shoe.

Equalized shoe pressure obtained regardless of wheel width.

The control machines were designed for operation by one man in each tower, but are so arranged that two men can be used during periods of peak business. The control machine in tower B is divided into two units, so located that the operator in throwing a switch lever looks toward the switch he is handling.

The power house is located on the south side of the southerly ladder track and is of concrete block construction. It has three separate rooms, the generator room, the battery room and the maintainers' room. A hot water heater in the maintainers' room heats these rooms and the junction tower A located on the second story.

The power house is furnished with two sources of outside power : 25-cycle, 3-phase power from the engine terminal at 550 volts; and 60-cycle, three phase City power at 440 volts. In addition there is a 258-volt bank of Exide batteries as a standby in case both alternating current sources fail. Normally the plant is operated by a 25-cycle motor generator set from Boston & Maine power. Should either source of alternating current power fail the storage battery is automatically cut in. The storage battery is charged with small generator sets by either source of power; or, if necessary to recharge quickly, by both generator sets (one 25-cycle—the other 60-cycle) run in parallel.

Hot oil system. — Hot oil is applied to the journals of cars just prior to their going over the hump. This consists of heating car oil with steam to about 180° F. and squirting it into the boxes under pressure. This insures free rolling cars in the severest weather.

Signals. — A color-light hump signal located at the crest, giving four speed indications, is repeated the entire length of the receiving yard by three repeaters, which show the signal indication in both directions. Klaxon horns for use during fogs are situated between each two signals insuring quick response by the engineman at all times.

The signal indications are also shown on the junction tower control board, and the operator at this tower can at any time set the hump signal at stop. The indications used are:

Yellow.	Slow hump speed.
Double yellow	Medium hump speed.
Green	Fast hump speed.
Red	Stop.
Yellow and red	Back up.

Communication. — Loud speaker telephones connect the hump with both towers for instant communication between the conductors and operators, while the switching lists are sent from the yard office to the hump and the towers by electric teletype machines. In addition to this there are local and public telephones between the various parts of the yard. Pneumatic tubes are being installed to facilitate the sending of bills and train lists from the receiving yard to the yard office and from there to the outward yard clerk.

Yard lighting. — The yard is lighted throughout its length by flood lights on towers located to throw the light lengthwise with the tracks.

Traffic. — The traffic at this yard, which is the western gateway of the Boston & Maine, is made up of three distinctly different classes. It consists of about 15% perishables from the south and west, 25 % merchandise from the west, and 60 % coal from the Pennsylvania and West Virginia coal fields. Substantially all freight switched in this yard is eastbound. The New York Central delivers its trains at Rotterdam, about 20 miles west of Mechanicville, from where Boston & Maine crews haul them to Mechanicville for switching. The Delaware & Hudson delivers freight directly to the Boston & Maine receiving yard. About 900 cars are received daily from these two connections, which with the cars from the l. c. l. transfer, repair tracks and ice house requires the humping of about 1 100 cars daily, with peak days far in excess of this amount.

Economies. — The yard has only been in service one month. At present, in order to train retarder operators two men are being used in each tower on all tricks and frequently three. The results, so far, indicate that with one man in each tower 125 cars an hour can be humped; and, with two men in each tower, 250 cars an hour. The operation to date has shown a decrease in yard costs of about 40 %; a decrease of 50 % in the time cars are held in the receiving yard and a material reduction in damage to cars in humping; and it is believed that the combined net annual savings will be in excess of 50 % of the cost of the entire work of providing the added facilities.

[656 .256 (.42)]

An ingenious semi-automatic signalling installation.

Provision for steam and electric working between Bow Road and Barking on the Tilbury Section of the London Midland and Scottish Railway.

Figs. 1 to 14, pp. 584 to 593.

(*Modern Transport.*)

Towards the end of February 1928 the third and last section of a new installation of semi-automatic signalling on the Tilbury section of the London Midland and Scottish Railway was brought into service, the first two sections having been in use for some months with material advantage to the train working. The signal engineer is responsible for the scheme and for the erection of the signals, train stops, detectors, etc., whilst the telegraph superintendent has designed the electrical equipment, and his staff has carried out the whole of the wiring, track circuiting and electric locking. The up and down electrified (local) lines, to which we refer, and which are shown on the accompanying diagram, form an eastward extension of the Whitechapel and Bow Railway. From Campbell Road Junction they extend on the north side of the up and down through (steam) lines, while from the east end of Little Ilford to Barking they run between the branch lines and the through lines. There is a junction at Bromley with the North London section of the London Midland and Scottish Railway from Broad Street, and one at Upper Abbey Mills Junction with the London and North Eastern Railway to North Woolwich. There are also a number of junctions between the electrified and steam lines.

Traffic considerations.

The branch lines are the steam lines to and from St. Pancras, via South Tottenham and Kentish Town. The through lines are connected with the London and North Eastern Railway at Gas Factory Junction, south of Bow Road, and they carry the very heavy passenger traffic passing between Fenchurch Street and Southend and Tilbury. This traffic may be termed « outer suburban,» and the train density at peak periods is such that it is impossible to use these lines for the « inner suburban » traffic between Bow Road and Barking. The inner suburban traffic is, therefore, confined to the up and down local (electrified) lines, which, by way of Bow Road, Whitechapel and Aldgate East, afford connection with the Inner Circle line and the Metropolitan District Railway. There has been a steady growth in the inner suburban traffic for many years, and the London County Council housing scheme at Becontree, on the east side of Barking, has added considerably to the numbers using these lines. As is usual in all London inner suburban areas, the main flow of traffic is inwards to the City in the morning, with a peak period between 7 a.m. and 9 a.m., and outwards from the City in the evening, with a peak period from 5 p.m. to 7 p.m., except, of course, on Saturdays when it is earlier. The majority of the trains run between East Ham, or Barking, and Ealing, Richmond, Wimbledon or Hounslow.

Former working methods.

There are eleven signal boxes between Campbell Road Junction and Barking, which are connected with the working of the electrified lines, and each of these also controls the working of through and/or branch steam lines. The signalling system, which was installed at the time of the widening and electrification to Barking from 1904 to 1908, namely, manual signalling with Sykes lock and block, together with mechanical train stops working with signals on the up and down local (electrified) lines, has been remarkably efficient, and at peak periods from 20 to 24 electric trains per line per hour have been worked, in addition to the heavy traffic on the steam lines. This service had, however, to be reduced during foggy weather, but this notwithstanding, it is believed that no other system of block working would have given the same results, providing, as it did, a check on the signalman's movements with a minimum of operations for belling, accepting, and clearing each train.

Signalling required for increased service.

Although the maximum number of trains worked per line per hour was 24, a rearrangement of the Sykes block sections and the respacing of signals would have provided for several more trains per line per hour; but to increase the number of electric trains to the maximum desired by means of mechanical signalling was impossible, mainly owing to physical and safety considerations, whilst to operate the block instruments, bells and levers would absorb too large a percentage of the train time interval. It has been generally acknowledged for many years that the only satisfactory method of dealing with intensive electric traffic is by means of automatic or controlled automatic signalling, and in this case, owing to the presence of junction and siding connections, controlled automatic signalling was decided upon, and no purely automatic signals are provided. The subject was carefully examined by the signal engineer in order to decide if there was a known system suited to the particular conditions. The occasional use of the electric lines by steam trains not fitted with train trips and not all fitted with continuous brakes, their greater use in the event of accident or derailment on the steam lines, the crossing of trains as at Bromley, East Ham and Barking, together with the retention of manual signalling Sykes lock and block on the steam lines : all these points presented a number of difficulties somewhat unusual in the re-signalling of intensive traffic lines.

A novel system.

The problem was a new one, and there was nothing in existence on other railways which gave promise of a satisfactory solution; consequently the signal engineer had to devise a system to fit it. Before he perfected what may be considered one of the most novel of modern signalling installations, a great deal of ground was covered in plotting out the effect upon the traffic movements of the various propositions. Multiple aspect signalling was considered, and although this would have been of value to steam traffic, it would have adversely affected the main electric traffic. He therefore ultimately decided to employ two-aspect signalling, and to make special provision for the working of the steam trains requiring to use these lines. Day colour light signals were also decided upon instead of semaphores, mainly on account of dark backgrounds; as the sight is good, distant or repeater signals are generally unnecessary, but to meet the restricted visibility during fog or snow, fog repeaters have been provided, with a consequent saving in fog-signalmen.

Details of installation.

With a view to increasing the carrying capacity to a maximum, the electrified lines have been track circuited throughout, and « normal clear » two-aspect colour light signals, with fog repeaters and train stops, brought into use; these are operated by the continuous track circuits and are controlled by mechanical levers in the signal boxes. The presence of points and crossings at most places, the restricted spaces, and the necessity to cater for « hit and miss » traffic, exercised an effect upon the signal positions; the gradients also influenced the problem, but it was possible to adopt the following general principles :

1. That two-aspect signals should not be placed apart at less than electric train deceleration distance.
2. That in order to avoid emergency braking, the fog repeaters should be placed at electric train deceleration distance from the signals they where to repeat.

It was thought that the adoption of the second principle would fulfil a useful purpose when fog did not prevail, as the positions would act as marker posts up to which trains could travel at normal speed before commencing to decelerate if the signal ahead were at danger. In arranging the train berths at stations consideration had also to be given to platform awnings, staircases and foot-

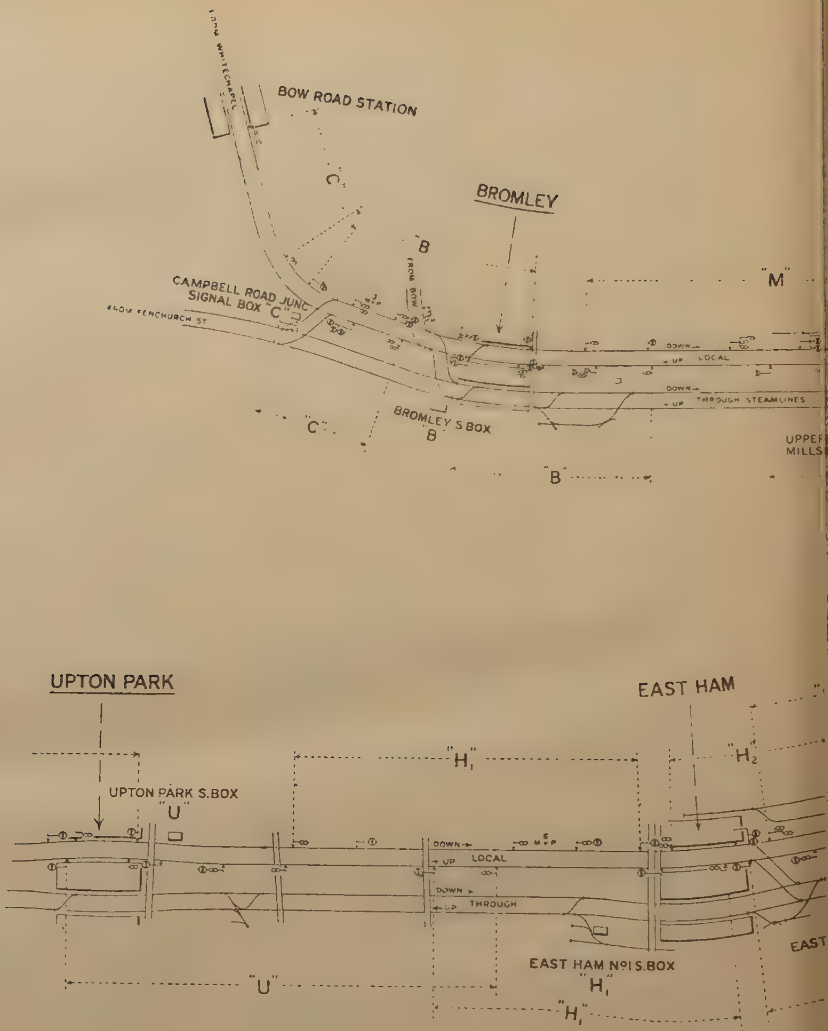
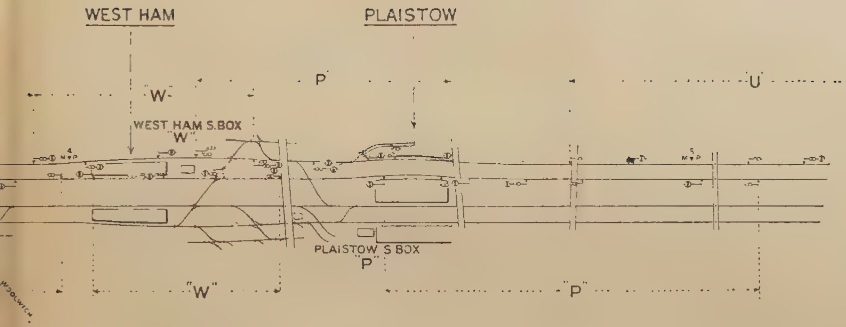
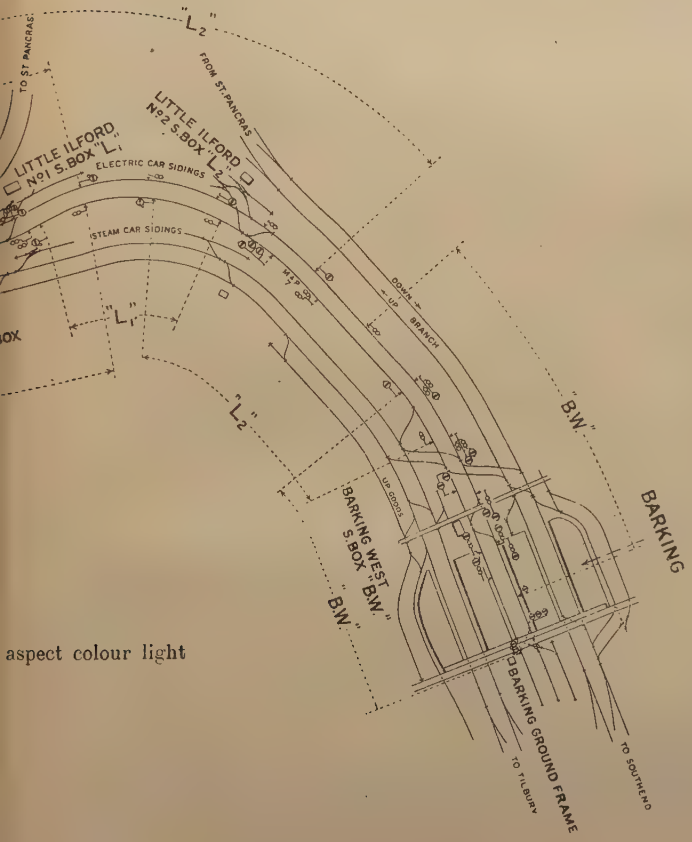


Fig. 1.

Diagram of the Bow Road-Barking section,
London Midland and Scottish Railway (Midland Division), shewing semi-auto
signalling as recently installed on the local electrified





aspect colour light

bridges to facilitate passenger movement.

Power supply and distribution.

As direct current is used for traction purposes it was essential to install a type of track circuit which would be unaffected by possible leakages from the traction supply, and, as alternating current track circuits became necessary, it followed that it would be more convenient to operate the entire apparatus from this supply. To guard against failure, current is obtained from two sources, and energy is taken at 440 volts, 50-periodicity, single-phase, from the West Ham Council supply, and also from that of the City of London Power Company at the signalling substation at Plaistow, whence it is distributed throughout the installation. Two 440-volt signalling mains are run in each direction from the substation, one main being fed from each supply, so that, normally, half the energy required is taken from one source of supply and half from the other. It is carried through automatic switches in the substation, so that, in the event of a failure in either supply, the full load is automatically transferred to the live supply main and divided again when normal conditions are resumed. The signalling mains are led into alternate transformer huts, one of these being fixed adjacent to each signal box. By this arrangement each of the signalling mains normally carries half the load, the advantage being that, in the event of a cable fault, the faulty section can be disconnected at the transformer hut and the load transferred to the other one. All the energy required at each signal box is taken from the main transformer in the hut, where it is stepped down to 110 volts. The existing signal boxes and mechanical lever frames have been retained. All points, facing point locks, and shunting signals, in addition to the signals for the steam lines, are still worked mechanically, and for the colour light signals the levers operate circuit controllers off the lever tails.

Signals and fog repeaters.

The signals are fitted with separate lenses for each aspect, *i. e.*, red and green. The main signal lenses are of 8-inch diameter and are exceedingly efficient in bright sunlight. They are arranged to give a diagonal light to the driver at close quarters. The bulbs, which are of the concentrated filament type, differ slightly from usual practice, as double filaments are used in such a way that one filament is under-run, the main filament being rated at 12 volts 24 watts and the auxiliary filament at 14 volts 12 watts. It is expected that by this means the auxiliary filament will have a longer life than the main filament, and, should the latter break, the auxiliary filament will give sufficient light until the bulb is replaced. Dimming switches are provided in the signal boxes to reduce the brightness of the lights during darkness. Each switch connects a choke coil in circuit, which reduces the voltage at the signal lamp to 8 volts. Dimming is especially necessary in this case, as the mechanically operated signals on the through lines are lighted by oil lamps. Back lights are not provided. The few repeater and calling-on signals are of the short range type with a lens diameter of 6 inches, except that the normal white light of the calling-on signal is of 1-inch diameter. Constant indication of all colour light signal aspects is provided over the control levers in the cabins; these are of colour light type. The fog repeaters are also fitted with separate lenses for each aspect, as follows:

Lunar white with word « Fog » in black letters: signal at « Danger ».

Green: signal at « Clear ».

They are switched in by the signalman during fog or snow. In cases where the fog repeater for the next signal ahead is fixed below a colour light signal, when the signal on which it is fixed is at danger no indication is given by the repeater.

Track circuits and overlaps.

As the traction current is carried by means of third and fourth rails, both running rails were available for track circuiting purposes, and impedance bonds were not necessary. The whole of the track circuiting is of the condenser fed type, with two element vane relays located as near as possible to the commencement of each track, as it was considered that there would be no advantage in concentrating them at the signal boxes. The track relays, track transformers and track condensers are housed in cast iron cupboards fixed on concrete blocks, and the connections between the running rails, track feed and relays consist of bare copper wire laid in grooved boxing fixed flush with the ballast. Suitable overlaps are provided on all colour light signals, and the overlap track circuit, or circuits, maintain the last two signals at « danger ».

Approach and route locking.

The usual route locking is provided by means of approach locks on the signal levers, normal and reverse locks on the points, and facing point lock levers. The locks are all fitted with a « throw-down » arrangement, which forces the locking bolt into the locked position each time the lever is moved to the position in which it should become locked, but, in addition, the locking bolt will fall in by gravity alone. Combined circuit controllers and electric locks are used, these being fitted on the same base plate; the advantage of this combination is a great reduction in the length of wiring required. Sealed releases are provided to the approach locks of the signal levers for use in emergency. The mechanical signals which give permission for entering or crossing track circuited lines are also locked by track circuits, and suitable arrangements have been made for the transference of traffic from Sykes lock and block territory to controlled automatic, and *vice-versa.*

Train stops and proving.

At each light signal position in the running lines an electric train stop is provided, which works with the signal. These are not indicated directly in the signal boxes as in the case of the light signals, but « train stop proving » has been provided. This arrangement is an ingenious one; it provides that, in the event of a train stop failing in the « off » position, the signal next in the rear will not exhibit a « clear » indication until the track circuits controlling the signal at which the train stop has failed are clear. The wiring of the signals and train stops is so arranged that, on the appearance of the « green » aspect, the « red » aspect is maintained for a second or so until the train stop has moved from the trip position. The failure of a train stop in the up, or trip, position is thus indicated at the signal and in the signal box by the exhibition of both red and green lights. The light repeater in the signal box can thus be used to indicate a failure of the train stop in the « off » position, as in such a case the red indication will be withdrawn immediately the green is exhibited. All facing points and locks in the electrified lines, and also trap switches, are electrically detected by the colour light signals, and constant indication of the detection is given in the signal boxes.

Telephones.

At certain signals which are situated some distance from the signal box a telephone is provided for the use of the driver or motorman should he be delayed at the signal for more than one minute. The instrument is of the waterproof mining type and is fixed in a cupboard at or close to the signal post.

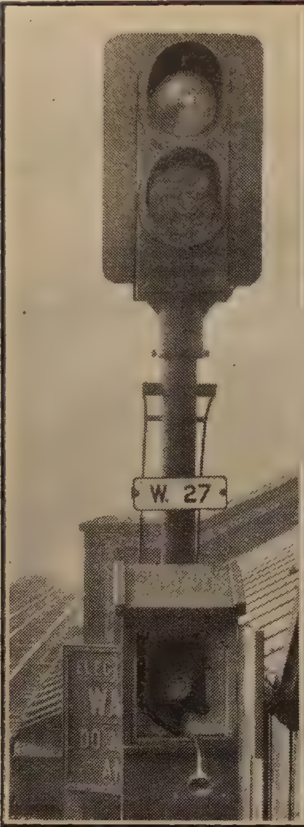


Fig. 2. — Driver's telephone on West Ham up local starting signal.

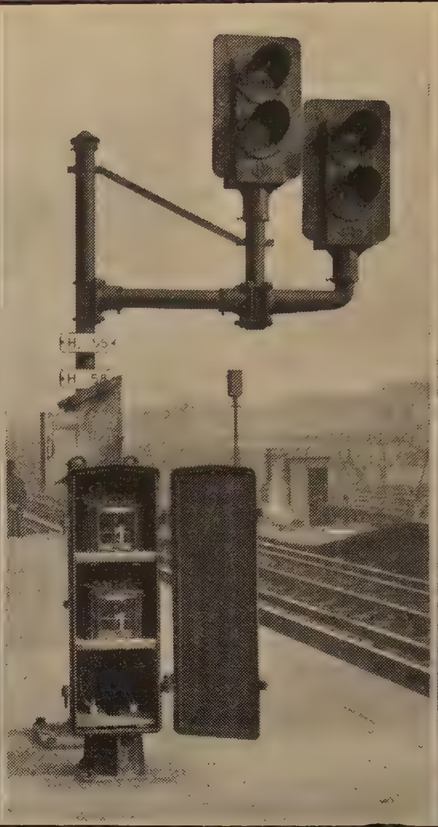


Fig. 3. — Down local signals on station platform, East Ham, with relay box on separate pedestal.

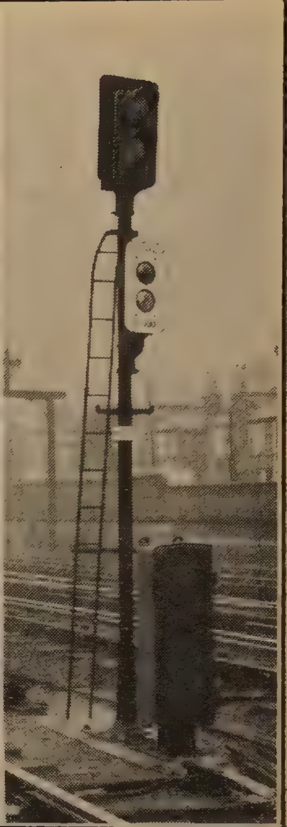


Fig. 4. — Up local signal, near East Ham No. 2 box, with fog repeater.

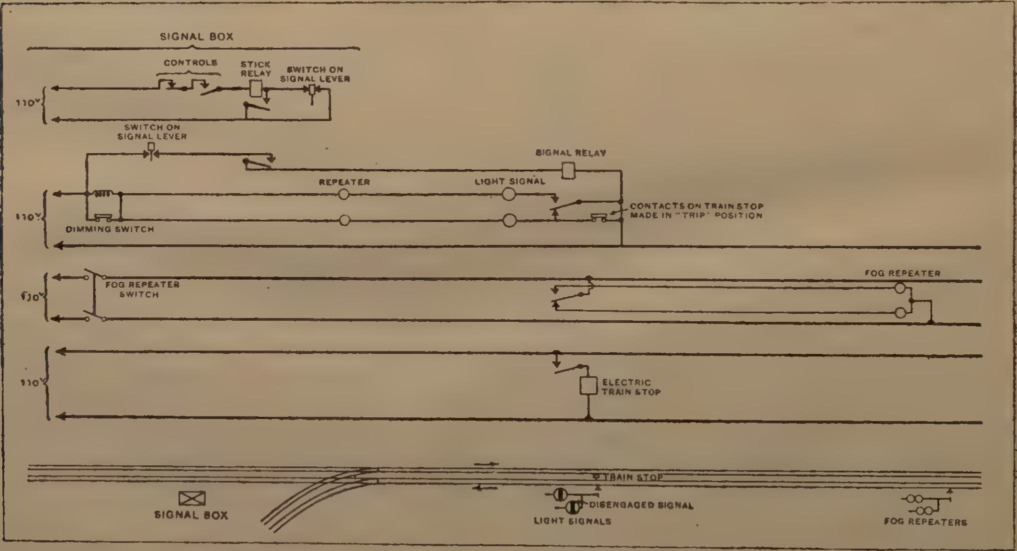


Fig. 6. — Wiring diagram illustrating light signal working on disengaged system.

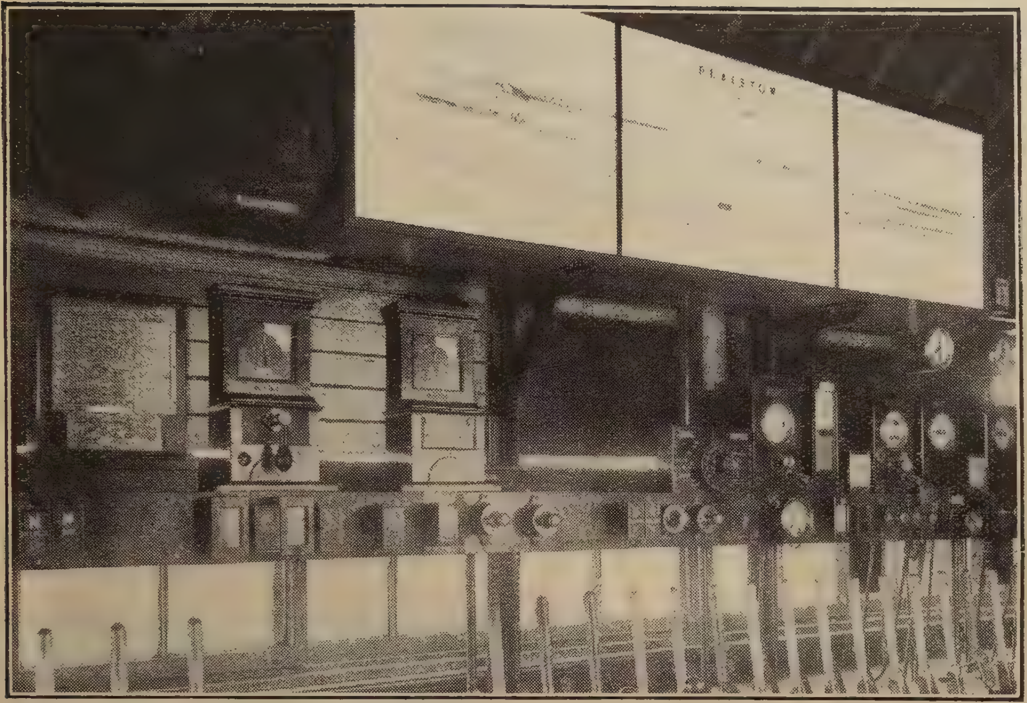


Fig. 5. — Interior of Plaistow signal box shewing illuminated diagram and instruments. The train destination indicator described in the text may be seen on the extreme left.

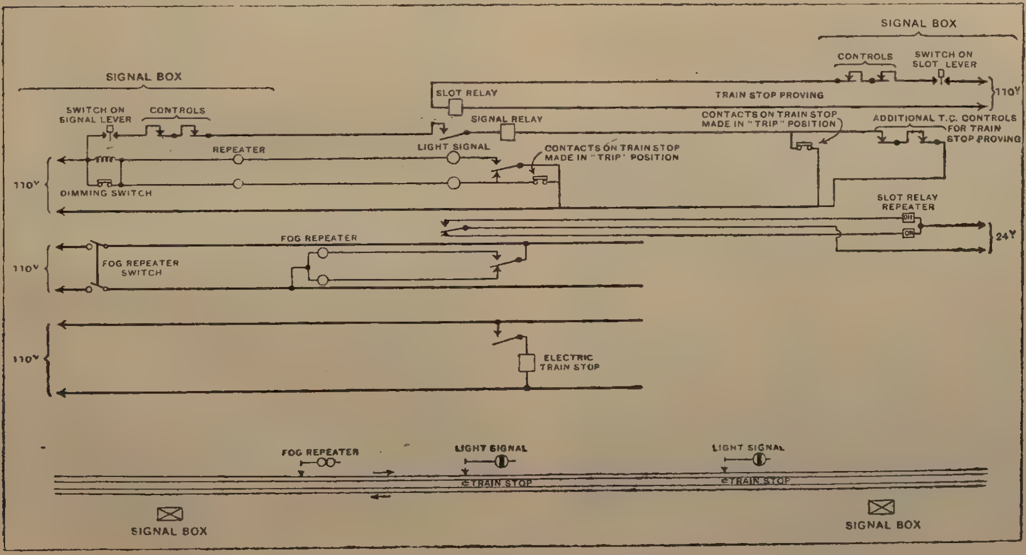


Fig. 7. — Wiring diagram of light signal controlled from two signal boxes.

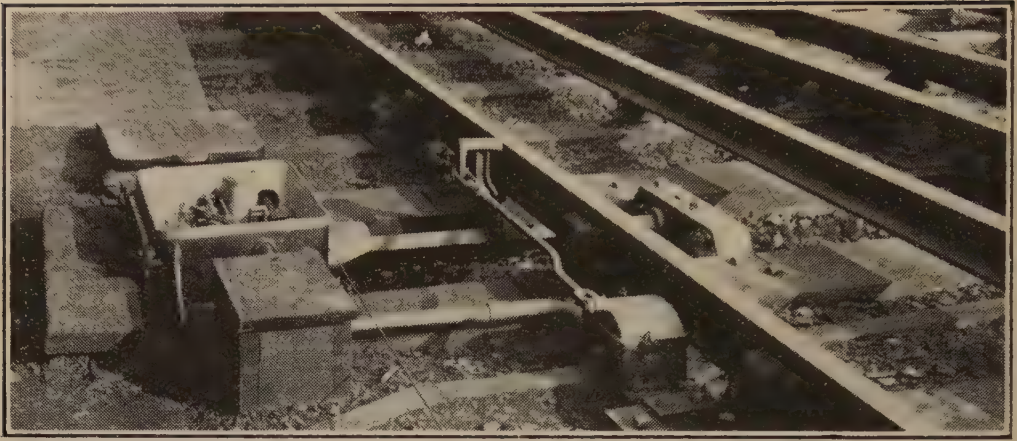


Fig. 8. — Automatic train stop (cover removed), West Ham up starting signal.

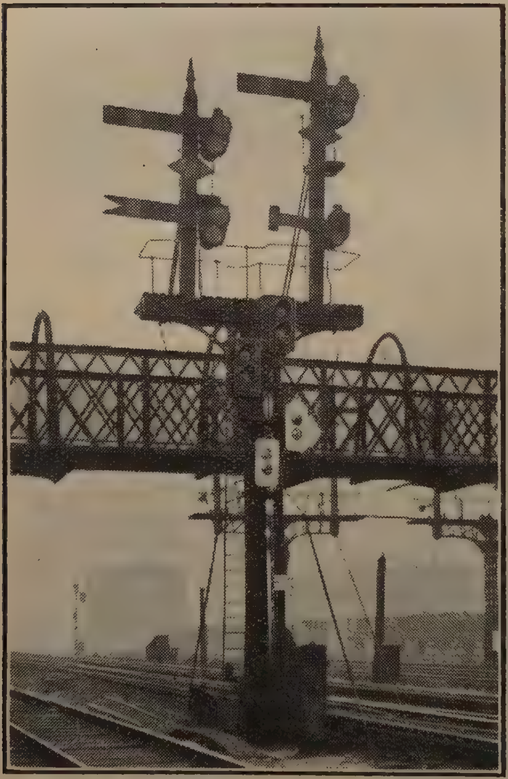


Fig. 10. — Down local signals, with fog repeaters,
and the semaphore signals they have replaced,
East Ham No. 2 box.

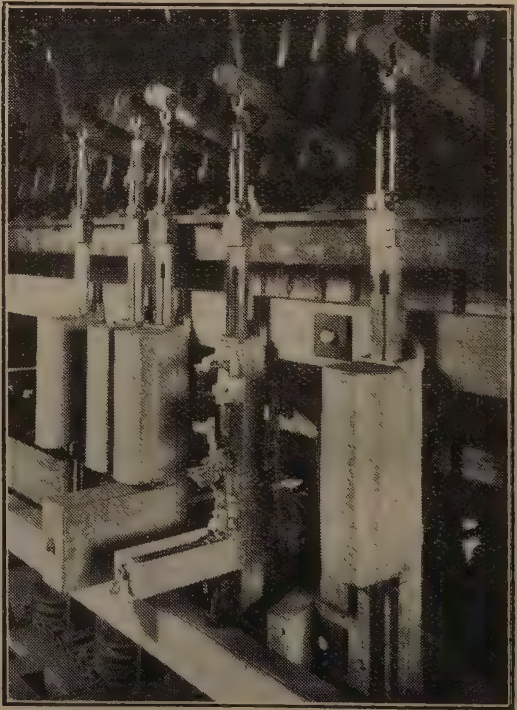


Fig. 11.
Lever locks connected up with mechanical levers,
Upper Abbey Mills Junction cabin.

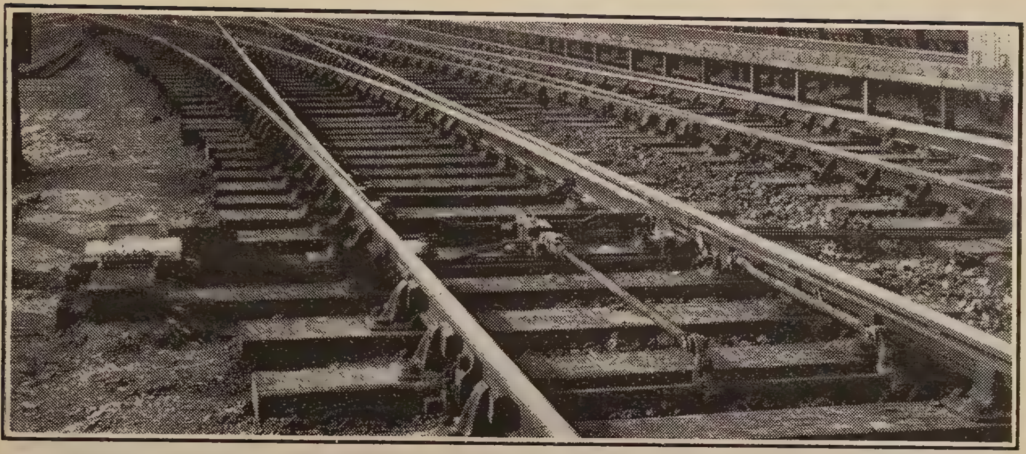


Fig. 9. — Facing point lay-out, shewing point detector and lock bar, down loop to up local line, East Ham.

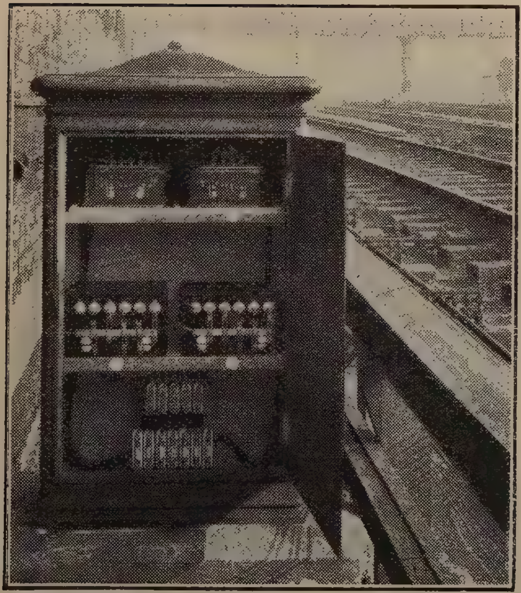


Fig. 12.
Relay case, near No. 2 cabin,
East Ham.

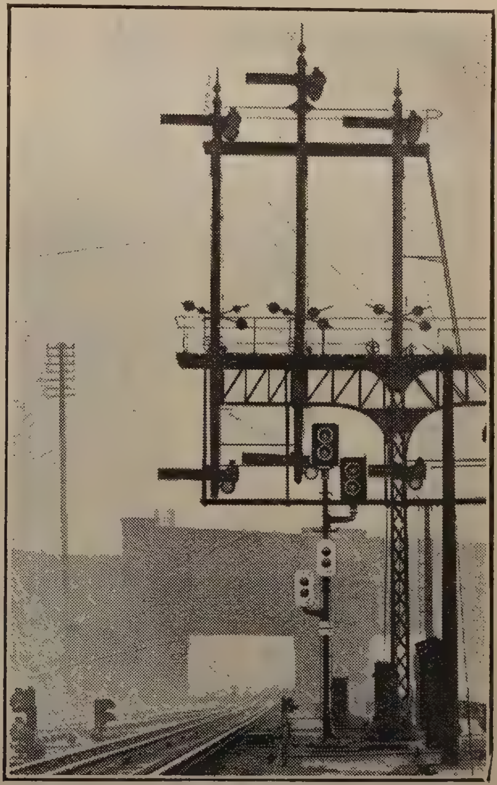


Fig. 13. — Down home signals, West Ham South box;
another view demonstrating compact nature
of the new signals as compared with the old.

Calling is effected by raising a lever on the side of the telephone, which causes an indicator to drop and a bell to be rung in the signal box; the bell continues to ring until the indicator is restored by the signalman. Separate indicators are provided for each signal but only one telephone is provided at each signal box for all the signal telephone circuits. Immediately below each indicator is a jack for the insertion of the telephone plug, but the insertion of the plug does not cut off the indicators from the lines. All indicators and jacks are plainly labelled with the number of the signal to which they apply, and when a signal box is closed the signal telephone circuits are automatically switched through to the signal box in advance.

Diagrams and train describers.

Diagrams of strip light pattern are provided at each signal box to indicate the whole of the section from the overlap of the starting signal in the rear. Train describers are provided from Bromley to Plaistow, and from Upton Park to East Ham No. 2 and Little Ilford No. 1 on the down local line, and from Barking West to Little Ilford No. 2 on the up local line. They are of the magazine type, the first two trains only being indicated. The trains are described by hand at the transmitting end, and cancelled automatically by the track circuits or by hand at the receiving end. The necessity for these describers is best illustrated by the consideration of the following particular case. Reference to the diagram shows that the down local line at Plaistow has one facing junction to the down through line, and another to the bay line. The down home signals, as has already been mentioned, are approach-locked by the track circuits; it is obvious, therefore, that the signalman must put the home signal lever back before a train gets on the approach track, otherwise he is unable to set the junction points for the required direction, and it is thus essential that advance information should be given as to the destination of the train. Block working has been abolished on the local lines, but the single stroke bells have been retained, and trains are signalled on the bell under a revised code devised for this purpose.

Steam train working.

The large number of electric trains made it imperative that the signalling should be arranged to suit the electric traffic, and special arrangements were necessary to deal with the few steam trains which travel over the electric lines at other than peak periods. A very complete scheme of steam train protection was worked out, but, after full consideration, was ultimately discarded owing to the complicated work involved. At the times steam trains require to use the electric lines a suitable interval between a steam train and the preceding train can be arranged, but, as the steam trains are not fitted with trip gear and require a greater breaking distance, special indicators have been provided to indicate to the signalman that automatic working has been suspended, and that the line is clear for a sufficient distance to allow a steam train to proceed. The indicator is operated by the signalman at the signal box in advance, by turning a handle on the apparatus to « Clear for steam train ». The handle cannot be placed to this position until the signal levers have been placed to « danger » and the track circuits are clear to the steam acceptance point, nor will the indication be given until the starting signal lever is put back in the frame. The signalman does not pull his starting signal lever again for a steam train until the indicator for the section ahead indicates « Clear for steam train », and until this indication is given, he brings the train step by step from signal to signal in accordance with General Rule 40a. As soon as the steam train clears the normal electric overlap track circuit, the indicator handle automatically assumes the normal position, and an electric train can follow close up behind the steam train with the same amount of headway as an electric train following another electric train. To enable the signalman to carry out General Rule 40a correctly at signals a long way from the signal box, or out of sight, « annunciators » are provided, which are operated by treadles at about 300 feet before reaching the signals.

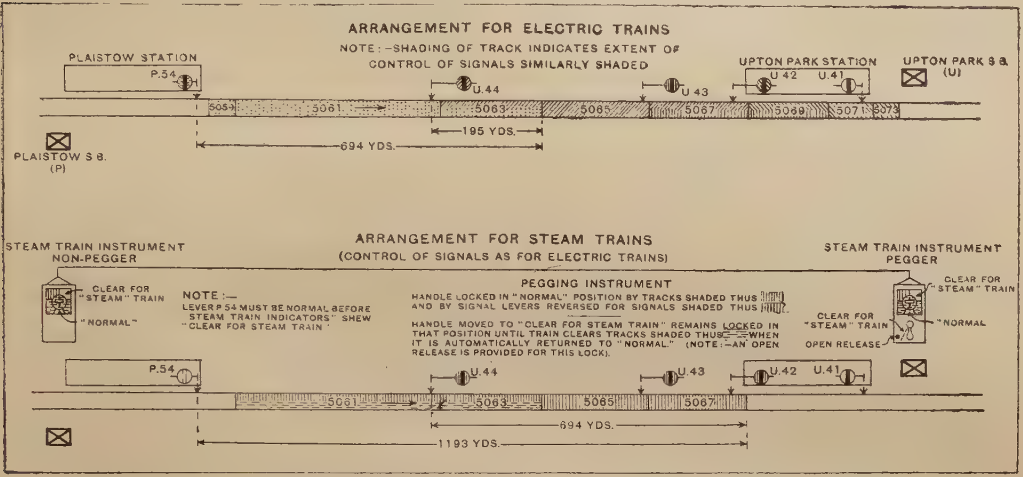

ARRANGEMENT FOR ELECTRIC TRAINS
NOTE: –SHADING OF TRACK INDICATES EXTENT OF CONTROL OF SIGNALS SIMILARLY SHADED
PLAISTOW STATION
P.54
U.44
U 43
UPTON PARK STATION
U 42
U.41
UPTON PARK S B. (U)
5059
5061
5063
5065
5067
5069
5071
5073
195 YDS.
694 YDS.
PLAISTOW S B. (P)
ARRANGEMENT FOR STEAM TRAINS
(CONTROL OF SIGNALS AS FOR ELECTRIC TRAINS)
STEAM TRAIN INSTRUMENT NON-PEGGER
STEAM TRAIN INSTRUMENT PEGGER
CLEAR FOR "STEAM" TRAIN
"NORMAL"
NOTE:— LEVER P 54 MUST BE NORMAL BEFORE STEAM TRAIN INDICATORS" SHEW "CLEAR FOR STEAM TRAIN"
PEGGING INSTRUMENT
HANDLE LOCKED IN "NORMAL" POSITION BY TRACKS SHADED THUS AND BY SIGNAL LEVERS REVERSED FOR SIGNALS SHADED THUS
HANDLE MOVED TO "CLEAR FOR STEAM TRAIN" REMAINS LOCKED IN THAT POSITION UNTIL TRAIN CLEARS TRACKS SHADED THUS WHEN IT IS AUTOMATICALLY RETURNED TO "NORMAL." (NOTE:–AN OPEN RELEASE IS PROVIDED FOR THIS LOCK).
CLEAR FOR "STEAM" TRAIN
"NORMAL
OPEN RELEASE
P.54
U.44
U.43
U.42
U.41
5061
5063
5065
5067
694 YDS.
1193 YDS.

Fig. 14. — Diagram indicating arrangements for steam and electric working.

Automatic cross-over at Barking.

At Barking Station there are only two platforms available for inner suburban traffic, and the permanent way layout will not permit of the service it is proposed to run in the future. It has been decided, therefore, to provide a new cross-over road leading from the down platform line to the extension of the up platform line at the east end of the station, and to work this cross-over road, and the signals connected with it, automatically, subject to control from Barking West signal box and the adjacent ground frame. The complete arrangements will be on the lines of the automatic working of a somewhat similar case on the Mersey Railway (described and illustrated in the 28 November 1925, issue of *Modern Transport* (1). At peak periods all trains will discharge at the down platform, and by the time station duties are completed the cross-over road and signal will have been set for the movement to the extended up platform line. As soon as the train is wholly off the cross-over, the cross-over points will be restored, the trap points will be closed, and the signal given for the train to enter the up platform line if that line is clear to the starting signal. In the accompanying wiring diagrams, it will be noticed that the various controlling circuits are operated by line relays; these are of the single element vane type and are concentrated at the various signal boxes, the relays being in turn controlled by the track relays located at the termination joints of the track circuits.

The whole of the signals, track relays, transformers, condensers and cast-iron cupboards were supplied by the Siemens and General Electric Railway Signal Co., Limited, of Central House, Kingsway, W.C. 2, whilst the line relays, train stops, train describers, and electric locks were furnished by the Westinghouse Brake and Saxby Signal Co., Limited, 82, York Road, King's Cross, N. 1. The entire work, as already mentioned, was carried out by the railway company's own staff.

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(1) See *Bulletin of the Railway Congress*, February 1926 number, p. 137.

[656 .253]

Speed signal aspects.

Flashing lights in railway working, ⁽¹⁾

By C. W. PRESCOTT,
CHIEF ENGINEER, METROPOLITAN VICKERS — G. R. S., LIMITED.

(*Modern Transport.*)

In automatic train control systems an endeavour is made to assist the driver in his duties by reminders and to control the speed of the train if he is incapacitated or forgetful. The indication given in the cab for this purpose must be a speed indication, because that is the only language the engine understands. The introduction of speed aspects on British railways would involve a radical change in the present signal practice, and a considerable expenditure for alterations to existing methods. It is natural, therefore, to ask : Is there any necessity for changing; who will benefit by the change, and what return may be expected from such expenditure ? It is suggested that the following conditions are reasons for the change :

a) The demand for increased track capacity.

b) The increasing adoption of electric traction, introducing an extra class of train with high acceleration and powerful brakes.

c) Longer non-stop runs, which increase the territory covered by individual drivers.

d) The increased speed of trains, which increases the number of signals to be observed per hour.

e) Increased engine power, which has had the effect of reducing the window space in the cabs, making it more difficult to view large groups of signals, such as some of our home signal bridges.

f) The desirability of reducing the necessary period of training of drivers.

g) The advantage to be obtained from easy transfer of drivers from one run to another.

The benefits will be felt by the railways as a whole in increased returns from investment in track and rolling stock, more efficient service from drivers using simplified aspects, which give them more information than they now receive, decreased cost of structures at interlockings, and greater standardisation of signal apparatus and controlling gear.

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(1) Abstract of a paper read before the Institution of Railway Signal Engineers, London.

The ideal condition.

Maximum track capacity would be gained if each driver could have before him on his engine a continuous indication of two essential factors which affect his running. These are : *a*) The length and condition of track ahead over which he is permitted to proceed, and *b*) the length of *that* track which he would traverse before coming to a stand if he were called upon to stop, plus or minus a factor dependent on the difference between the stopping distance of the train in question and the most powerfully braked train which might be ahead. With these two factors reduced to comparable terms, *i. e.*, expressed either in speed or distance, the driver could travel at maximum speed at all times and the maximum capacity of a track would be obtained, providing interlocking signals were efficiently operated. The track indication would be corrected for the track conditions, such as gradient curvature, and permanent speed restriction existing between the engine and the next « obstruction », be it the tail of the train ahead or a stop signal. The engine indication would be calibrated in accordance with the braking characteristics of the train as a whole. There is no doubt that this can and will be done in the future, but in the meantime, let us consider how closely we can approach to the above condition by means of fixed signals giving speed indications.

Limitations imposed by fixed signals.

If we could have two devices like route indicators at every signal, showing in plain figures the maximum speed at which the train might travel through the block governed by that signal, and the speed at which it should be moving when it reached the next signal, we would approach what we have called the ideal condition in which the signal is carried on the train. As this scheme would not differentiate between trains of different brake power, such as goods and passenger, it would be necessary definitely to divide trains into classes in this respect. The indication might be made to show the speed applicable to the most poorly braked train and the drivers of other trains would then use a conversion factor. This would not be as difficult as it sounds, and is not as bad as remembering route indications, because the same factor would apply to all signals, and so long as a driver is controlling one class of train he has no necessity to think of more than one factor. In all probability, were the scheme in use, an enamelled plate bearing the factor clearly on the face of it would be fastened in a conspicuous place in the cab by a responsible official when the train was made up. If the brake power of three classes of train were in the ratio of 1 for unbraked goods, 2 for the braked goods, and 4 for passenger trains, the indicated speed would require to be multiplied by approximately 1.4 for braked goods and 2.0 for the passenger. In practice, this would become 1 1/2 and 2, so that 20 miles per hour on the indicator would mean 20, 30 and 40 miles per hour respectively, to the drivers of the three classes of train.

Speed indication.

The display of indicators instead of, or even in conjunction with, signals, is not feasible, because they cannot be read at sufficient distance. In the case just considered, a train might pass a signal enforcing 20 miles per hour for the length of the block and at the instant it passed, conditions might change to permit of a speed of 40 miles per hour, but the driver would not be able to avail himself of the new indication with respect to the block he is occupying. He might see a higher speed indicated at the next signal, but that would not authorise him to increase his speed before he reached that signal unless he knew that there was no permanent restriction in the block. There is, therefore, a necessity for a distinction between a permanent speed restriction and a removable one depending on conditions ahead, and this is not provided for in the present standard aspects. Reduction of speed while passing through the block is covered, but increase of speed is not. If speed indications are to be generally adopted in England, they should, if possible, be such as not to be confined to colour light signals nor should they necessarily require electricity, at least during the transition stage. Further, since we cannot have infinite gradations, we must consider how many proceed aspects are feasible and what speeds they should represent.

Signal spacing.

The speeds chosen must bear a definite relation to one another *for the minimum spacing of signals.* The low speed will have a stopping distance much less than the minimum spacing of signals, but the next higher, say, medium speed, must at least be such that a train may be brought to a stand in the space between signals. This space must be sufficient to allow the speed of a train to be reduced from the next higher, say, normal speed, to medium speed, and from a further speed if employed, say, high to normal. This means roughly that for trains having similar retardation, the following approximate relations hold good :

Medium.	*Normal.*	*High.*
20	28	35
25	35	44
30	42	52

If we consider signals 1 200 feet apart, and that this is braking distance for a goods train at 30 miles per hour, then we would have the following speeds for medium, normal and high on the assumption of brake powers, 1 for unbraked goods, 2 for braked goods, and 4 for passenger :

Medium.			*Normal.*			*High.*		
UG	BG	P	UG	BG	P	UG	BG	P
30	42	60	42	59	84	52	72	—

These figures are to give an idea of relationship only. The « materials » to hand at present include arms capable of three positions, three long-distance colours — green, yellow and red, and a short range light — purple and lunar white, which is a distinctive light and which might be used in combination with some of the others. Use may be made of position, colour and a combination of these two to differentiate aspects.

Repeaters.

The most flexible method of giving information respecting the signal in advance is by a separate distinctive signal which repeats its aspect. This repeater signal must be safeguarded, so that it cannot be mistaken for a home signal or display a proceed indication at the same location as a home at « stop ». The three-position signal is more economical than the separate repeater in arms, lights, and, with power-worked signals, in mechanisms. It is desirable that a repeater signal should be returned to its most restrictive indication immediately the train passes it, and, when this is done, the extra cost of adding a stop indication (a red light) and making it a block signal, is generally trifling compared with the advantage obtained. Even if the signals, when correctly spaced for the anticipated headway, do not require a stop signal at the repeater location, it is an asset when traffic is congested. When three or four different proceed aspects are required, the difficulties of repetition are increased.

Speed aspects.

Speed signal aspects have followed the lines of one arm (or light) one speed, up to the present, and, so far as can be ascertained, have only been used with three-position signals. There appear to be other methods which might be considered in places where the three-position aspects are not standardised. It is more important to have speed indications than to adhere to the world-wide interpretation of the three-position signal, and it is not essential that the stop and repeater indications be displayed by the same signal. The necessity for repeating the signal in advance, is to tell the driver what he is expected to do while passing through the block, in order that he may obey the indication of the next signal when he reaches it. There are only three things he can do : 1. Reduce speed; 2. continue at a speed not greater than that allowed by the signal; or 3. accelerate, if the signal ahead permits. If, therefore, a distinctive signal giving three indications — say, reduce, continue, and accelerate — could be devised and used in conjunction with speed aspects, these would not have to be increased, even though the number of the proceed speed aspects were greater than three.

Flashing signals.

It has been proved in marine signalling that an intermittent or flashing light is a very arresting indication and can be seen farther than a fixed light at night. This principle might be applied to signal lights to give a second indication with one colour. Reliable flashing arrangements can be obtained, both for electric and other lights, and these could be used with mechanical or electric signals. If the flashing indication is admitted to be practicable, we then could increase the indications of signals very usefully. For instance, a two-position signal can give two proceed aspects : Stop — steady red; proceed at medium speed — steady green; proceed at normal speed — flashing green; or three, if flashing red would be considered as a call-on. If this is not considered desirable, a low speed or call-on may be obtained, as at present, by a separate arm or by a single light used in conjunction with the red of the signal. If more than three proceed indications are required, the three-position signal might be used, giving four proceed indications visible at long range, as follows :

Horizontal, steady red : stop;
45°, steady yellow : low speed;
45°, flashing yellow : medium speed;
90°, steady green : normal speed;
90°, flashing green : high speed.

The two-position upper quadrant mechanical signal is being adopted on some of our railways, and a three-position mechanical signal is quite feasible. Therefore the above suggestions are applicable to mechanical as well as electric signals. Instead of a repeater, a lunar white light might be used to give the « continue » by burning steadily, the « increase » by flashing, and the « reduce » by being absent, and if this were adopted, automatic or stop and proceed signals might be differentiated from interlocked or « stop and stay » by any desired marker. If it is agreed that permanent speed restrictions are so few as to be satisfactorily covered by some other sign, then the flashing of the « repeater » could be dispensed with and a steady white used to show that the next indication may be obeyed on sight.

In conclusion, it may with confidence be asserted that speed signal aspects of any efficient type will reduce junction signals to the limit of simplicity and make their indications uniform at all places. They are necessary to enable track to be used to its maximum capacity by reducing the space between trains in relation to their speed and braking characteristics, and they simplify the links in the chain of communication between the signalman and the driver.

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Some lessons of the Sevenoaks accident,

By C. F. DENDY MARSHALL, M. A., M. I. Loco. E.

(*The Railway Engineer.*)

The able report by Sir John Pringle on the subject of the derailment which occurred near Sevenoaks in August 1927, undoubtedly contains all the matters of fact which can be arrived at in connection with it, and most of the conclusions that can safely be drawn from them. Such deductions are necessarily circumscribed and brief in an official report, and some interest and perhaps profit may be derived from an examination of the facts with a fuller and less restricted discussion.

It is most satisfactory that, whereas in the 20 years 1885 to 1904 there were 100 inquiries into derailments, during the 23 years 1905 to 1927, only 40 were required. And this result is in face of the fact that engines have been getting heavier all the time, while the appropriate strengthening and reconditioning of the track is bound to lag behind the increase of weight, since any given section is only relaid at fairly long intervals. Probably the weight itself is the principal factor that has brought about this improvement, the engines running more steadily, in the same way as a heavy motor-car gives more comfortable riding.

The test runs after the accident have brought out several valuable facts. The engines ran more steadily bogie first than forwards. Here we have a distinct indication that bogies are preferable to ponies for the leading ends of engines to be run at high speeds. These particular engines are of an ideal design for making this comparison, being otherwise practically symmetrical. There is, of course, one condition which is radically different in the two directions, namely, the position of the cylinders and of the disturbances set up by the reciprocating parts. But a moment's thought will show that the pressure on the slide-bars, of which more presently, tends in both cases to lift the end which is leading.

The running was better with tanks full than nearly empty, a result which at first sight looks as if tanks, or equivalent weights in their position, might be an advantage at high speeds. If this is not so, as it can hardly be, the effect must have been due to surging of the water when there was room for it to do so. In order to hinder water from passing from one tank to the other during a roll, the diameter of the connecting pipe should be kept down to the smallest figure compatible with avoiding delay when the tank on one side is being filled.

The tank engines rolled more than a tender engine on the same pieces of line. How far is this greater steadiness of the latter due to the restraining influence of the tender, with its own period of rolling, which is unlikely to coincide or harmonise with that of the engine? Probably not entirely, but the point should be borne in mind when designing the couplings. In the report the greater stability of the tender engine is attributed to stiffer springing, which at the same time is condemned by Mr. Gresley because it is damaging to the track. The vibration of this engine was very severe.

The use of spring-compensating levers is suggested. These appliances are a palliative for a bad track, as they distribute shocks, but have never been found essential in this country, although applied occasionally. In America they are always employed, for which there may be a special reason, to be discussed later.

A valuable feature of the accident is that it has given an indication of the rolling period of engines of this type, since the pair of wheels which first went off left distinct markings, first one side and then the other, revealing a period of from 1 1/4 to 1 3/4 seconds. The report contains a profile of the outer rail showing the super-elevation, which was insufficient everywhere, and very irregular. I have tried to project the rolls backwards from the point where the first wheel mounted, in order to see if there was any relation to the ups and downs of the rail, but without much success, except that there is a very good start for a roll at the end of the transition, which, by the way, « transgressed » the wrong way. But we are not given the true profile of the rail in space, only with reference to the other rail, which was probably just as badly out of level, and may have had a share in augmenting the rolls.

This report clearly shows the great importance of keeping the vertical alignment of the rails as nearly true as possible. It is not sufficient for the platelayers merely to ram the ballast firm. Each rail should be carefully levelled from end to end, or if there is a gradient, set at precisely its correct inclination to the horizontal.

Nothing is said in the report about the fact that the stresses on the rails caused by individual axles at high speeds differ materially from those set up by the observed loading when the engine is at rest, nor is the extent of this variation generally realised. Some experiments carried out in America by Mr. H. F. Roach show the vital importance, from the point of view of the permanent-way man, of placing only a moderate weight on the trailing wheels. He drew a straight white line on the side of the rail, and photographed it during the passage of an engine, subsequently magnifying the result, in a vertical direction only, by 400. Some of the photographs he obtained, which are reproduced in my book *The Resistance of Express Trains* (1) show that the rail is distorted in a series of peaks, one under each wheel, like an inverted mountain range. At the slowest speeds the slope commences some distance ahead of the engine, and recedes sharply at the tender. But in the case of a 4-6-2 engine running at 55 miles an hour the slope only begins about the middle of the bogie. The peaks under the other wheels increase to a maximum under the trailing wheel, the distortion being nearly maintained under the first tender wheel, even there being considerably greater than under the driving wheel. This effect is principally one of hysteresis, owing to the stiffness of the rail, but there is another factor, also not generally recognised, tending in the same direction, which is the « trim » of the engine at speed. An express engine is in some ways like a fast launch; she not only displaces the track like the latter does the sea, producing rail-creep, but actually sets up in front, reducing the weight on the leading wheels, and increasing that behind.

This tendency was first pointed out by Mr. Marié, in his valuable *Traité de stabilité du matériel des chemins de fer*, published in 1924. There are three causes : the air pressure on the front, acting in this case at a centre about 8 feet above the rail; the tractive pull at 3 1/2 feet up; and, much the most important, the upward pressure on the slide-bars. The following rough calculations indicate the order of the effect. The engine is nearly symmetrical, and we can take it she turns about the line joining the points of contact of the driving wheels with the rails. The leading wheels are 16 ft. 1 in., or 193 inches, from the drivers.

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(1) *The Resistance of Express Trains*, by C. F. Dendy Marshall, M. A. Published by *The Railway Engineer*, 33, Tothill Street, Westminster, London, S. W. I. Price 20sh.

From Table II of my book we find that the frontal pressure in a calm on an engine of 100 square feet area at 60 miles an hour is 821 lb. The uplift due to this cause is therefore about 410 lb., a figure which may be more than doubled in a high wind. We have now to consider what pull the engine is capable of exerting at 60 miles an hour. With 200-lb. boiler pressure and a pair of cylinders 19 inches by 28 inches driving 6-foot wheels, it is fairly considerable. The maximum tractive effort is 10 to 10 1/2 tons. The train weighed 250 tons plus load, and was on an up gradient of 1 in 160, the effect of the gradient alone being therefore 1 3/4 tons or so, to which must be added its resistance. There would, of course, be a reduction due to deceleration. On the whole, it is probably safe to assume that the pull might reach 2 tons, though it could not be maintained at that speed for any length of time. The effect would therefore be

$$4\,480 \times \frac{42}{193} = 965 \text{ lb.}$$

That of the slide-bar pressures is more difficult to estimate. As it may be a new idea to some people that they are a serious disturbing force it may be well to show how they operate on the weight and balance of the engine. Suppose the stroke is increased until it is equal to the radius of the wheel. Let the crank-pin be at its lowest point, and the brake hard on. It is now easy to see that if steam is turned on in front of the piston there is a pressure upwards on the slide bar and downwards on the rail. If pressure is applied behind the piston, the opposite occurs. A consideration of the state of affairs when the crank-pin is up will show that the pressure is still upwards on the bar and downwards on the rail when going forward. The maximum pressure would occur about half-stroke if there was no expansion; but the effective pressure is coming down fast from the moment of cut-off.

The actual pressure on the bar at any moment is $P \tan \phi$, where P is the total pressure on the piston and ϕ the angle of the connecting rod to the centre line of motion. With a 6-foot wheel at 60 miles an hour, the maxima on one side, being two per revolution, occur 9 1/3 times per second. If we assume the maximum to be when the crank is at a right angle to the connecting rod, and the pressure in the cylinder at that moment to be 100 lb. per square inch, taking the length of the connecting rod to be 8 feet, which it appears to be from the drawing, the value, for one side only, is

$$\frac{100 \times 19 \times 19 \times 22 \times 14}{2 \times 2 \times 7 \times 96} = 4\,136 \text{ lb.}$$

Such impulses as these, applied with such rapidity, will probably produce a permanent uplift of at least 3 600 lb., especially as earlier in the stroke, although the angle is smaller, the steam pressure is greater. It occurs on both sides, the centre of its application being just about half-way between the leading and driving wheels, and the total effect on the former is therefore 3 600 lb.

Summing up we have :

Air.	about	400 (which may be 1 000 in a gale)
Pull	—	1 000
Slide bars . .	—	3 600
Total. . .	—	5 000 lb.

or well over 2 tons, being about 20 % of the 11 tons on the leading wheels in the present case, showing that trim is clearly a matter to be reckoned with, especially if an engine is inclined to pitch, and suggesting that a speed limit is desirable for engines with a pony in front, also that centring arrangements operated by springs are preferable to those depending on gravity.

Locomotives engineers could borrow some ideas with advantage from motor-car practice. It is interesting to hear that a windscreen wiper is being tried, but there is more than that. I have before pointed out the absurdity of leaving train speeds to guesswork when every cheap little car has a speedometer. Such a fitting would be especially valuable in the dark, when it and the other instruments should be lit up electrically. Moreover, all the lamps should be electric.

In Colonel Mount's report on the Den of Cowie derailment, attention is called to the desirability of having substantial wheelguards and check rails on bridges and viaducts, splayed at the ends, to keep vehicles which have been derailed close to the alignment of the track. The Sevenoaks disaster suggets that these safeguards might be equally valuable where the line passes through overbridges, an idea which does not seem to have occurred to anyone before.

There is one last point which is, I submit, worthy of the careful consideration of American engineers. It is connected with the rail-joints. Coming, as they do, at regular intervals, they are a potential danger if at any attainable speed their impacts can come into unison, or even harmony, which the natural periods of the vehicles. We set them in line with one another. With 45-foot rails, at 61 miles an hour the joints come every second. The period of pitching, induced by parallel joints, is probably far quicker than this. But when, as in America, they are set alternately, their tendency is to set up a roll, the period at 61 miles an hour being a second. In my book I pointed out the possible danger of this arrangement, without knowing what the rolling period of an engine might be. From the report under discussion it appears that the period shown by the damage to the track was from 1 1/4 to 1 3/4 seconds, and as shown by an accelerometer on a normal run 1 to 1 1/10 seconds in the case of the tank engines, but less with the tender engine.

It therefore appears that there is considerable risk about the alternative method, because the impulses, though only small, are regular, and the question arises, how do the American engines stay on the rails ? I have come to the conclusion that the spring compensating systems are their salvation, as they destroy the rhythm and distribute the impulses; that the arrangement of rail joints is the cause of the apparent indispensability of these appliances in America, as compared with their superfluity over here; and that the millions of dollars spent in supplying the engines with them for all these years might have been saved if the rails had been set with their joints together.

656 .1 (.44) & 656 .2 (.44)]

Railway road services in France.

Developments of the Paris, Lyons and Mediterranean Railway autocar system.

Figs. 1 to 3, pp. 603 to 606.

(*Modern Transport.*)

Unhampered by extensive legislative restrictions, the French railway companies have been able, during recent years, to make very extensive developments in the organisation of road passenger services, especially in the more picturesque parts of the country frequented by tourists. One of the pioneer companies in the adoption of these services was the Paris, Lyons and Mediterranean Railway, the first road passenger service of which system was inaugurated in 1909, when M. Margot, the present director-general, then chief engineer of the running section, saw the enormous advantages possessed by motor coaches for tourist services in the mountainous districts of France, which were untouched or very sparsely served by the railways. Simultaneously with the proposal for the operation of such services in the French Alps, the Touring Club of France launched its plan for the establishment of a touring road, known as the « Route des Alpes », to extend from Nice to Evian, via the mountain passes. Over a considerable portion of the route, roads were already in existence, and only needed local improvements. The only important section which required to be constructed was one between the upper Arc Valley (Bonneval) and the upper Isère Valley (Val d'Isère), over the Iseran Pass, at a height of 9 085 feet above sea level, the terminating point of the projected touring road. Owing to the difficulty in plotting the exact route to be followed and later the financial crisis following the war, this road has still to be constructed, but fortunately a different road was available in this section, and, although regarded at the time as being somewhat dangerous, the « Route des Alpes » was opened to passenger automobile traffic in 1911.

Equipment of coaches

From this comparatively small start has sprung the widespread road services, more than two hundred in number, now operated by the Paris, Lyons and Mediterranean Railway and its concessionnaires. Under the present system of operation all services are leased to local companies. These concessionnaires are free to operate any type of chassis they choose, but, for purposes of safety and general convenience, the railway company requires that the equipment of the vehicles should include servo brakes on all wheels, a second braking system independent of the servo brakes, and, in addition, all vehicles must be fitted with electric lighting and starting equipment and with a klaxon horn. All vehicles are fitted with motors of 20 H. P. rating. The types of vehicles in general use by the concessionnaires include Berliet, Cottin-Desgouttes, Delahaye, Renault and Rochet-Schneider. In all cases the railway company requires that each passenger shall have a large armchair seat. The

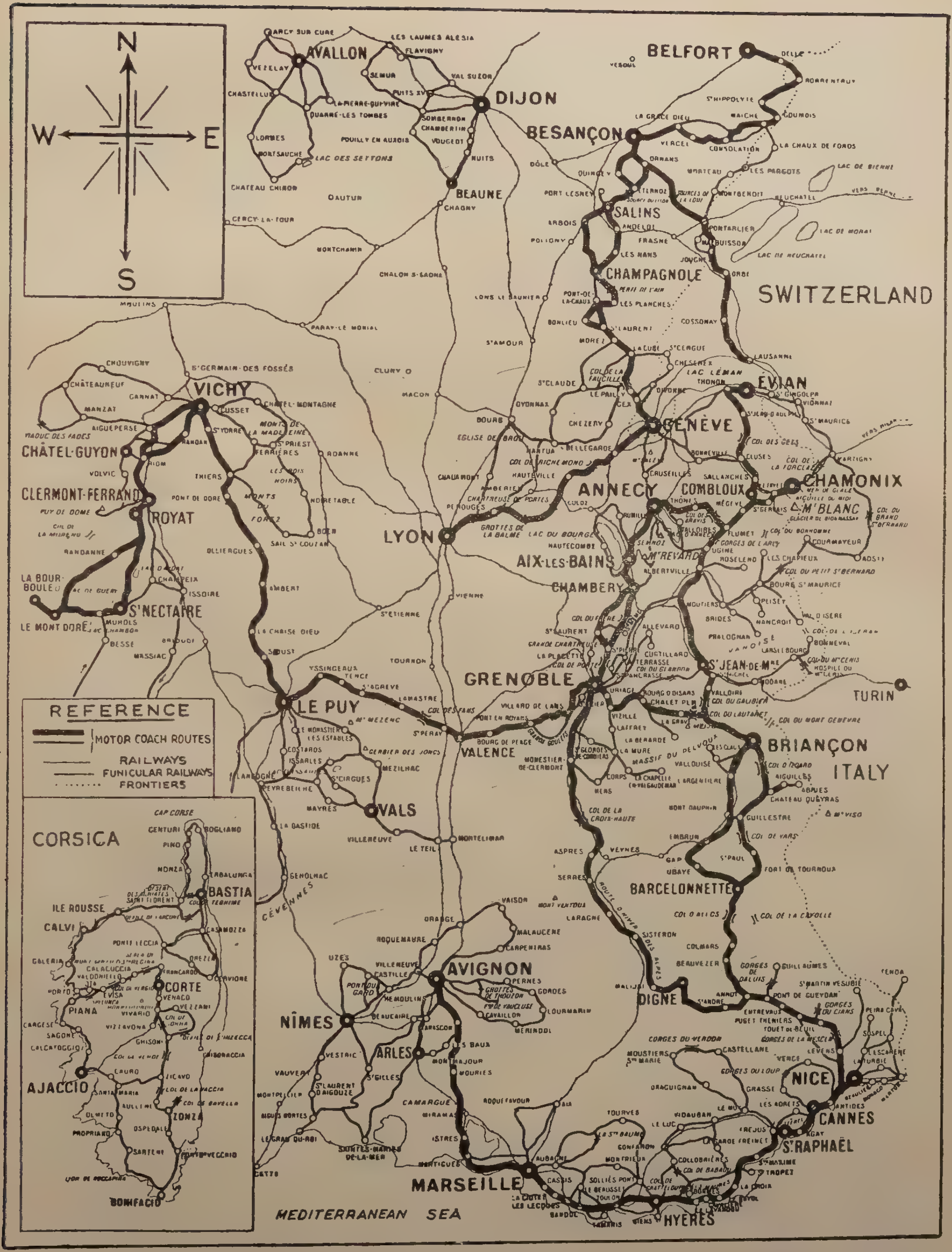

Fig. 1. — Map shewing the extent of road passenger services of the Paris, Lyons and Mediterranean Railway.

number of these seats to a coach is either eleven or fourteen, according to the type of coach, and the seats are arranged across the coaches in rows of three. All chassis and bodies are built as low as possible and the doors are large and numerous to facilitate mounting and alighting. The Paris, Lyons and Mediterranean Railway has fixed the following limits for weight and dimensions of coaches, in order that the vehicles may be as easy as possible to handle and that they may be able to negotiate the narrowest and most difficult roads likely to be encountered :

Eleven-seaters	Maximum weight	3 400 kgr. (3 tons 7 cwt.).
	Maximum wheelbase	3.6 metres (11 ft. 9 3/4 in.).
	Maximum width	2.1 — (6 ft. 10 3/4 in.).
Fourteen-seaters	Maximum weight	3 700 kgr. (3 tons 13 cwt.).
	Maximum wheelbase	4.1 metres (13 ft. 5 1/2 in.).
	Maximum width	2.2 — (7 ft. 2 5/8 in.).

New vehicles.

During the present year the railway company is undertaking a number of experiments in an endeavour to improve the various services. All concessionnaires have already been instructed to consider the introduction of coaches with bodies of the all-weather type. Several experimental vehicles of this type were introduced at the end of the last season, but a definite choice has yet to be made. A number of vehicles with semi-enclosed bodies have been in service for some years on the Corniche routes, described below; these are capable of carrying nine passengers in the covered saloon at the rear, and five passengers in the front open section. For the first time, also, a number of coaches with seats for only seven passengers are being introduced on the less popular routes during the present season. Twenty of these vehicles, equipped with two spare wheels and, in addition, two spare tubes, have already been put into traffic.

Vichy services.

Apart from a daily service between Paris and Fontainebleau, a total distance of 146 km. (90.7 miles) for the double journey, and three shorter services in and around the forest of Fontainebleau, all the road passenger services are in the departments to the south of Burgundy. From the towns of Dijon and Avallon there are five local services operated during the summer season; two from Dijon and three from Avallon. Four of these services run every two or three days, and the fifth daily. The distance covered by these services varies from 112 km. (69.6 miles) to 166 km. (103.1 miles) the maximum fare being 70 francs. Passengers are carried for portions of the journey at the rate of 50 c. per kilometre. Apart from the Alpine services, the famous spa Vichy is the principal inland centre for the Paris, Lyons and Mediterranean road services. There are seven local circular sight-seeing routes, in addition to four services operated jointly by the Paris, Lyons and Mediterranean and Paris-Orleans Railways and the important cross-country service from Vichy to Grenoble. The latter service is operated every other day in each direction, and two days are necessary to cover the journey of 401 km. (249.2 miles). In each direction an overnight stop is made at Le Puy. Coaches leave Vichy and Grenoble every Monday, Wednesday and Friday, and pass through the picturesque towns of Thiers, La Chaise-Dieu, Allègre, Sainte-Agrève and Valence. The fare for the through journey is 210 francs single, and 370 francs return. Shorter journeys may be made at the rate of 70 c. per kilometre. This through service is operated by two separate concessionnaires, one working the Grenoble-Le Puy section and the other being responsible for the remainder of the route. From both Vichy and Le Puy special three-day trips are operated during the summer season to the celebrated Gorges du Tarn. The fare for the former trip is 360 francs for the complete circuit of 841 km. (522.6 miles), while that for the Le Puy service, which is a biweekly one, is 250 francs for the journey of 484 km. (300.7 miles), including a short steamer trip.

Alpine services.

During the past few years some of the most popular of the Paris, Lyons and Mediterranean road passenger services have been those linking the various Alpine resorts with the Riviera, Geneva and Lyons, and the north. Owing to climatic conditions considerable variations have to be made in the routes in winter time, the existence of snow and ice making it impossible for the roads used in summer to be followed. For example, the principal summer service from the Côte d'Azur is from Nice, via Beauvezer, Barcelonnette, Briançon and St. Jean de Maurienne, to Chamonix, this journey being accomplished in two and a half days, overnight stops being made at Briançon and Beauvezer. In winter time the Riviera-Alps service is via Digne, Grenoble, Aix-les-Bains and Annecy, overnight stops being made at each of the first three places. Chamonix is the terminus for no less than five long-distance road services, in addition to a large number of local circular sight-seeing tours, being linked with Geneva, Evian, Annecy, Grenoble and Briançon in one or two-day stages. An extension from Geneva places the popular Alpine resort in direct road communication with Lyons, while a steamer from Evian to Ouchy, across Lake Leman (Lake of Geneva) provides connections with Besançon and Belfort. A special service — an extension of the original « Route des Alpes » — is now operated from Nice during the months of June, July, August and September. This journey is covered in eight daily stages, the route followed being : Nice-Annot-Barcelonnette-Aiguilles-Briançon-Le Lautaret-Grenoble-Aix-les-Bains-Annecy-Combloux-Chamonix-Evian-Ouchy (by steamer) — Besançon-Belfort-Besançon-Champagnole and Geneva. In summer time the fares for the various Alpine services vary between 60 c. and 70 c. per kilometre. In winter time, however, the average fare is about 80 c. per kilometre. In both cases considerable reductions are made for passengers who travel the whole journey. In most cases the services are operated daily in each direction.

Côte d'Azur routes.

Considerable efforts have been made during the past two years to extend the Riviera season throughout the whole year, and the success which has resulted has compelled the Paris, Lyons and Mediterranean Company to operate their many services in this district throughout the year instead of only during the winter season as hitherto. The various Corniche roads between Marseilles and the Italian frontier are covered by the long-distance services. Between St. Raphael and Cannes the Paris, Lyons and Mediterranean Railway, in conjunction with the Touring Club of France, have constructed a wide coast road known as the « Corniche d'Estérel », which has made accessible some of the most recondite sites of beauty on the whole of the Côte d'Azur. Services are operated daily between Marseilles and Nice. The first of these leaves both termini at 7.45 a. m., and reaches its destination at 7.45 p. m., stops for lunch being made at Cavalière on each journey. A second service on the same route

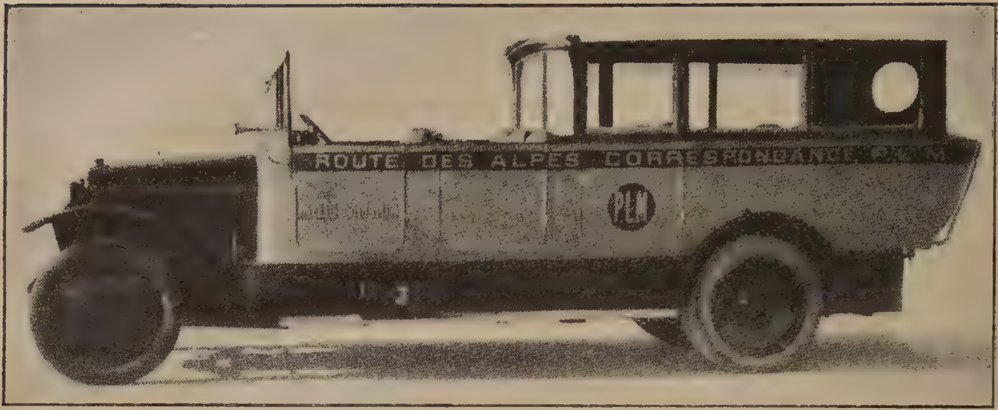

Fig. 2. — A fourteen-seater semi-enclosed motor coach, with nine interior and five outside seats, used on the « Route des Alpes » road passenger service on the Paris, Lyons and Mediterranean Railway.

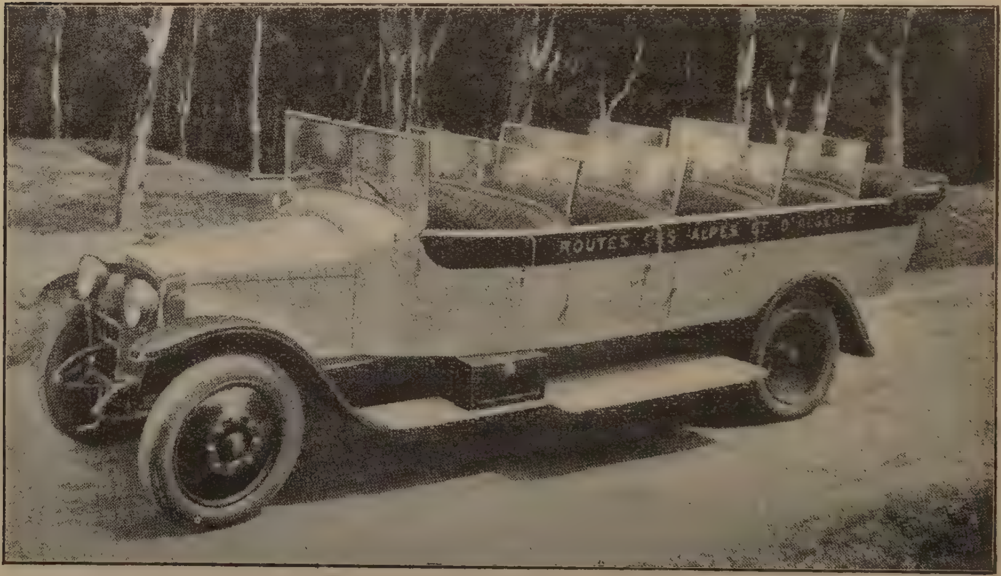

Fig. 3. — One of the fourteen-seater coaches employed on the « Route des Alpes » and the Algerian road passenger services of the Paris, Lyons and Mediterranean Railway.

covers the distance in a day and a half, the passenger having the opportunity of staying overnight at either Toulon or Hyères. On both services the fare for the journey (277 km. [172.1 miles]) is 150 francs. Shorter journeys can be made between certain places at the rate of 60 c. per kilometre. Apart from these « Routes du Littoral » there are a number of local coach services between the various coastal resorts. In addition a large number of circular sight-seeing tours are organised from Nice, Cannes, St. Raphael, Hyères, Toulon, etc. In the case of the latter services an inclusive charge is made for the complete trip, but in the inter-resort services, the fares are approximately 50 c. per kilometre with reductions for long distances. Marseilles is linked by road services with Avignon, the former city of the Popes, from which a large number of local circular services are operated to Nîmes, Arles, Les Baux, Pont du Gard, Orange and other picturesque towns and villages.

Corsica and North Africa.

In both Corsica and Algeria there are many services of Paris, Lyons and Mediterranean autocars, special facilities being offered for extended tours of the rugged mountains of Corsica and also for trips well into the Sahara Desert. In Corsica, Ajaccio, Bonifacio and Bastia are the centres for the road services, being linked by frequent steamship services with both Marseilles and Nice. Circular tours, in many cases covering two days, are operated to all the principal villages in the interior of the island. The fares in most of these services are 80 c. per kilometre, with the usual reduction being made for long distances. In Algeria many of the longer services are operated in conjunction with the « Compagnie Générale Transatlantique » and with the Algerian State Railway (C. F. A. E.). The services in this colony cover all the popular desert oases, including Biskra, Touggourt, Ghardaia, Laghouat and Bou-Saada. Many of the tours extend over ten to fourteen days, giving the tourists ample opportunity of seeing the Sahara. Many local excursions are operated in the neigbourhood of Algiers, covering both the coast and the more picturesque points of the hinterland.

Auxiliary services.

The increasing popularity of the Paris, Lyons and Mediterranean road services has resulted in the introduction of special vans to carry the passenger's luggage on many long-distance services. Facilities are afforded on all coaches for the transport of light baggage, but these have proved insufficient in many cases. Thirteen of these luggage services were introduced in 1927, and the vehicles covered a distance of 130 000 km. (80 780 miles) during the year. The charge for the carriage of luggage in these vans is 1 franc per 10 kgr. (22 lb.) per 10 km. (6.2 miles). The number of road passenger services operated by the Paris, Lyons and Mediterranean concessionnaires during 1927 was 200, covering a total route mileage of 10 200 km. (6 338 miles). During the year 210 000 passengers were carried, and the passenger vehicles covered a total distance of 2 531 000 km. (1 572 700 miles).

MISCELLANEOUS INFORMATION

[313 .385 (.5)]

1. — The World's railways during the years 1922, 1923, 1924 and 1925.

COUNTRIES.	Mileage open on 31 December				Area (square miles).	Population.	Mileage open at the end of 1925	
	1922	1923	1924	1925			per 100 square miles.	per 10 000 inhabitants.
I. — EUROPE.	Miles.				Round figures.		Miles.	
Germany.								
Prussia (including the Sarre)	21 119.5	21 022.6	21 153.1	21 248.2	113 750	38 795 000	18.7	5.5
Bavaria (including the Palatinate)	5 402.3	5 485.0	5 513.5	5 513.5	29 500	7 479 000	18.7	6.8
Saxony	2 003.9	2 003.9	2 022.0	2 018.2	5 790	4 992 000	34.9	4.0
Wurtemberg	1 391.9	1 393.8	1 415.5	1 427.3	7 530	2 580 000	19.0	5.5
Baden	1 504.4	1 505.6	1 508.1	1 496.9	5 830	2 312 000	25.7	6.5
Other German States . .	4 401.9	4 367.7	4 417.4	4 433.0	19 850	7 026 000	22.4	6.3
Total for Germany.	35 823.9	35 778.6	36 029.6	36 137.1	182 250	(1) 63 184 000	19.8	5.7
Austria	3 938.9	4 153.3	4 373.3	4 373.3	32 350	6 535 000	13.5	6.7
Czechoslovakia	8 718.0	8 718.0	8 718.0	8 718.0	54 210	13 613 000	16.1	6.4
Hungary	5 921.1	5 921.1	5 921.1	5 921.1	35 870	8 275 000	16.6	7.1
Great Britain	24 396.7	24 396.7	24 396.7	24 396.7	94 210	45 213 000	25.9	5.4
France	33 281.8	33 281.8	33 281.8	33 281.8	212 750	44 744 000	15.6	7.5
Russia	30 800.7	35 027.3	35 708.4	35 739.4	2 240 630	115 508 000	1.6	3.1
Finland	2 665.7	2 728.5	2 821.1	2 821.1	150 000	3 365 000	1.9	8.4
Poland	9 871.9	11 974.7	11 974.7	12 054.2	149 970	27 177 000	8.0	4.4
Lithuania	1 938.7	1 938.7	1 938.7	1 938.7	21 580	2 371 000	9.0	8.2
Lettonia	1 770.8	1 754.8	1 754.8	1 774.7	25 410	1 845 000	6.9	9.6
Esthonia	890.4	890.4	890.4	890.4	18 340	1 107 000	4.8	8.0
Italy	12 500.9	12 840.2	12 840.2	13 111.2	119 660	38 756 000	10.9	3.4
Belgium	6 893.0	6 893.0	6 893.0	6 893.0	11 740	7 812 000	58.7	8.8
Luxemburg	334.3	334.3	334.3	342.4	1 000	267 000	34.1	12.8
Holland	2 140.7	2 140.7	2 264.9	2 264.9	13 210	6 865 000	17.2	3.3
Switzerland	3 323.1	3 571.7	3 571.7	3 587.3	15 950	3 918 000	22.5	9.1
Spain	9 643.9	9 676.1	9 676.1	9 676.1	195 060	21 967 000	5.0	4.4
Portugal	2 129.5	2 129.5	2 129.5	2 129.5	35 480	6 033 000	6.0	3.5
Denmark	3 086.4	3 086.4	3 096.3	3 148.6	16 600	3 420 000	19.0	9.2
Norway	2 140.7	2 147.5	2 147.5	2 230.1	125 030	2 732 000	1.8	8.1
Sweden	9 436.3	9 555.6	9 765.0	9 765.0	173 170	6 006 000	5.6	15.9
Yougoslavia	5 699.3	5 699.3	5 699.3	6 118.1	96 030	11 997 000	5.8	5.1
Roumania	7 325.4	7 322.4	7 322.4	7 424.3	113 590	17 500 000	6.6	4.2
Greece	1 983.5	1 983.5	1 983.5	1 983.5	49 040	5 022 000	4.0	3.9
Albany	40.4	186.4	186.4	186.4	10 620	804 000	1.8	2.3
Bulgaria	1 624.3	1 624.3	1 624.3	1 639.2	39 810	5 483 000	4.0	3.0
Turkey in Europe . . .	257.3	257.3	257.3	257.3	10 430	1 000 000	2.4	2.6
Malta, Jersey, Isle of Man.	68.4	68.4	68.4	68.4	430	375 000	16.1	1.9
Total for Europe.	228 645.5	236 080.5	237 668.7	238 871.8	4 244 420	472 894 000	5.6	5.1

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(1) According to the census of 16 June 1925.

COUNTRIES.	Mileage open on 31 December				Area (square miles).	Population.	Mileage open at the end of 1925	
	1922	1923	1924	1925			per 100 square miles.	per 10 000 inhabitants.
II. — AMERICA.	Miles.				Round figures.		Miles.	
Canada	39 541.0	39 861.7	40 093.4	40 093.4	3 729 880	9 364 000	1.1	42.8
United States of America (including Alaska)	252 241.4	251 162.6	250 970.7	250 904.9	3 625 240	106 139 000	6.9	23.6
Newfoundland	950.7	952.6	952.6	952.6	162 940	263 000	0.6	36.2
Mexico	16 443.0	16 443.0	16 443.0	16 443.0	757 640	14 281 000	2.1	11.5
CENTRAL AMERICA :								
Guatemala	613.3	681.0	684.8	684.8	42 360	2 005 000	1.6	3.4
Honduras	559.3	811.5	811.5	811.5	59 580	760 000	1.3	10.7
Salvador	256.0	256.0	256.0	256.0	13 170	1 582 000	1.9	1.6
Nicaragua	200.0	200.0	200.1	200.1	49 150	638 000	0.5	3.1
Costa-Rica	545.6	667.4	667.4	667.4	18 760	507 000	3.5	13.2
Panama	297.6	469.1	469.1	469.1	28 760	446 000	1.6	10.5
GREATER ANTILLES :								
Cuba	3 005.0	3 722.7	3 722.7	3 722.7	44 210	3 123 000	8.4	11.9
Dominican Republic	408.3	408.3	408.3	408.3	19 340	895 000	2.1	4.5
Haïti	167.2	173.4	173.4	210.0	11 080	2 028 000	1.9	1.1
Jamaica	198.8	200.1	200.1	205.1	4 210	858 000	4.8	2.4
Porto-Rico	339.9	339.9	339.9	339.9	3 440	1 403 000	9.8	2.4
LESSER ANTILLES :								
Martinique	139.1	185.2	185.8	185.8	390	244 000	48.1	7.6
Barbadoes	497.8	497.8	497.8	497.8	160	159 000	322.2	31.3
Trinity	108.1	173.4	173.4	173.4	1 970	382 000	8.9	4.5
Antigua	...	...	19.9	19.9	110	29 000	17.2	6.8
Virgin Isles	...	...	29.8	29.8	80	5 000	38.6	59.7
Bahama Isles	...	...	9.9	28.0	4 400	53 000	0.6	5.3
St. Christofer (St. Kitts)	...	...	16.1	16.1	80	22 000	20.9	7.3
United States of Columbia	925.9	1 020.3	1 020.3	1 108.5	495 540	5 855 000	0.16	1.9
Venezuela	659.9	659.9	659.9	659.9	393 990	2 533 000	0.16	2.6
British Guiana	103.8	103.8	103.8	103.8	89 460	298 000	0.16	3.5
Dutch Guiana	37.3	37.3	37.3	107.5	54 330	136 000	0.16	7.9
Ecuador	651.8	651.8	651.8	651.8	224 220	2 000 000	0.32	3.2
Peru	1 988.4	2 075.5	2 075.5	2 089.7	523 190	5 550 000	0.32	3.7
Bolivia	1 502.5	1 502.5	1 502.5	1 502.5	614 000	2 990 000	0.32	5.0
Brazil	18 704.2	18 704.2	18 704.2	18 952.2	3 286 310	33 767 000	0.6	5.6
Paraguay	308.8	308.8	308.8	517.0	171 820	1 000 000	0.32	5.2
Uruguay	1 652.9	1 652.9	1 659.1	1 659.1	72 160	1 640 000	2.3	10.1
Chili	5 301.0	5 049.9	5 381.8	5 381.8	290 170	3 754 000	1.9	14.4
Argentine Republic	23 156.4	23 156.3	23 482.0	23 482.0	1 150 090	9 847 000	2.1	23.9
Total for America.	371 505.0	372 128.9	372 912.7	373 535.4	15 942 230	214 556 000	2.4	17.4
III. — ASIA.								
Central Russia and Siberia	6 556.2	7 083.8	10 185.7	10 550.5	6 191 370	30 712 000	0.16	3.4
China	6 837.6	7 173.2	7 173.2	7 469.0	4 370 830	441 200 000	0.16	0.2
Japan, including Corea, Formosa and Kwantung	12 284.1	13 109.9	13 109.9	14 032.1	262 440	84 567 000	5.1	1.7

COUNTRIES.	Mileage open on 31 December				Area (square miles).	Population.	Mileage open at the end of 1925	
	1922	1923	1924	1925			per 100 square miles.	per 10 000 inhabitants.
	Miles.				Round figures.		Miles.	
British India	(1) 40 491.1	(1) 38 068.5	(1) 38 068.5	(1) 38 571.7	1 892 700	319 647 000	2.1	1.2
Ceylon	731.9	732.6	732.6	732.6	25 330	4 505 000	2.9	1.6
Persia	350.4	350.5	350.5	134.8	(2) 628 210	10 000 000	0.016	0.12
Asia Minor, Syria, Arabia with Cyprus	3 828.9	3 828.9	3 828.9	3 828.9	1 418 280	21 311 000	0.32	1.8
Palestine	...	695.9	695.9	695.9	9 000	757 000	7.7	9.2
Portuguese Indies	54.0	54.0	54.0	57.2	1 620	579 000	3.5	0.9
Malay States	1 163.2	1 163.2	1 163.2	1 163.2	51 010	2 448 000	2.3	4.7
Dutch Indies (Java, Sumatra, Celebes)	1 882.7	1 894.6	1 894.6	2 971.5	788 370	49 543 000	0.32	0.37
North Borneo, Sarawak	...	...	139.8	139.8	78 960	889 000	0.16	1.6
Siam	1 422.9	1 538.6	1 538.6	1 547.2	200 090	9 724 000	0.8	1.7
Cochinchina, Camboja, Annam, Tonkin	1 490.0	1 490.1	1 490.1	1 490.1	270 590	19 844 000	0.5	0.7
Pondicherry	59.0	59.0	59.0	59.0	120	175 000	51.0	3.4
Philippine Isles	809.6	809.7	809.7	809.7	115 020	11 414 000	0.6	0.7
Total for Asia.	77 961.6	78 052.5	81 294.2	84 253.2	16 303 940	1 007 315 000	0.5	0.8
IV. — AFRICA.								
Egypt (including Sudan)	4 894.0	4 894.0	4 894.0	4 894.0	1 361 060	19 949 000	0.32	2.4
Algiers and Tunis	4 219.8	4 219.8	4 219.8	4 833.7	270 510	8 159 000	1.8	5.9
Marocco	861.9	884.9	884.9	884.9	160 240	4 330 000	0.5	2.1
Belgian Congo	1 263.3	1 273.2	1 273.2	1 273.2	920 930	7 153 000	0.16	1 8
South African Union	11 475.7	11 570.1	11 744.7	11 744.7	472 380	7 294 000	2.4	1.6
Colonies.								
ENGLAND :								
British East Africa (including Zanzibar)	851.3	692.9	692.9	(2) 692.9	431 990	5 945 000	0.16	1.2
Ex-German East Africa (Tanganyka)	891.7	891.7	1 019.1	1 022.2	365 110	4 124 000	0.32	2.5
Rhodesia	2 457.6	2 457.6	2 471.2	2 471.2	440 170	2 011 000	0.5	12.3
Betchuanaland	425.1	425.1	425.1	425.1	275 070	153 000	0.16	27.8
British Central Africa (Nyassaland)	173.9	173.9	173.9	173.9	39 960	1 212 000	0.5	1.4
Sierra-Leone	334.9	338.0	354.8	354.8	30 890	1 541 000	1.1	2.3
Gold Coast	193.9	193.9	302.0	302.0	78 610	2 108 000	0.32	1.4
Nigeria	1 125.9	1 125.9	1 125.9	1 125.9	336 080	18 071 000	0.32	0.6
South West Africa	1 307.4	1 413.6	1 680.2	1 680.2	322 450	228 000	0.5	73.7
Mauritius	133.6	144.2	144.2	144.2	730	377 000	19.6	3.9

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(1) According to a communication received from the Government of India, Railway Department, the correct open mileage of all railways in British India is as stated hereafter :

Year ending 31 March	1923	37 617.9 miles.
— —	1924	38 038.5 —
— —	1925	38 269.8 —

(2) Corrected figure.

(Editorial note.)

COUNTRIES.	Mileage open on 31 December				Area (square miles).	Population.	Mileage open at the end of 1925	
	1922	1923	1924	1925			per 100 square miles.	per 10 000 inhabitants.
	Miles.				Round figures.		Miles.	
FRANCE :								
French West Africa . .	1 713.8	1 713.8	1 713.8	2 069.8	1 853 360	12 283 000	0.16	1.7
Togo	203.2	204.5	206.3	206.3	20 080	671 000	1.0	3.0
Cameroun	192.6	246.7	282.7	282.7	166 530	3 000 000	0.16	0.9
French Somali Coast (Abyssinia)	495.2	495.2	495.2	495.2	8 490	65 000	5.8	76.2
French Equatorial Africa.	335.6	335.6	335.6	335.6	871 040	2 851 000	0.03	1.2
Madagascar.	402.1	435.6	600.3	600.3	242 210	3 382 000	0.32	1.8
Reunion	78.9	78.9	78.9	78.9	930	173 000	8.5	4.5
PORTUGAL :								
Angola.	818.3	818.3	818.3	818.3	484 880	4 182 000	0.16	1.9
Mozambique	454.8	454.8	520.7	571.7	294 990	3 120 000	0.16	1.9
Total for Africa.	35 304.5	35 482.2	36 457.7	37 481.7	9 448 690	112 382 000	0.32	3.4
V. — AUSTRALIA.								
New Zealand	3 011.2	3 029.3	3 084.5	3 200.1	103 900	1 426 000	3.1	22.4
Victoria	4 349.1	4 377.0	4 483.3	4 483.3	87 880	1 671 000	5.1	26.8
New South Wales . . .	5 443.9	5 477.5	5 654.6	5 654.6	309 430	2 272 000	1.8	24.9
South Australia	3 467.3	3 488.4	3 488.4	3 488.4	380 090	543 000	1.0	64.3
Queensland.	7 022.9	7 067.0	7 067.0	7 067.0	670 490	855 000	1.1	82.6
Tasmania	867.5	873.1	873.1	873.1	26 220	212 000	3.4	41.2
West Australia	4 839.3	4 869.8	4 869.8	4 869.8	975 950	368 000	0.5	132.2
North Territory	197.6	198.8	198.8	198.8	523 650	(¹) 4 000	0.032	497.1
Territory of the Federal Capital	4.9	4.9	4.9	4.9	930	(¹) 4 000	0.5	12.4
Hawaï (with the Isles Maui and Oahu)	242.9	242.9	242.9	251.6	6 450	292 000	3.9	8.7
New Caledonia	...	...	18.7	18.7	7 220	48 000	0.32	3.9
Total for Australia.	29 446.6	29 628.7	29 986.0	30 110.3	3 092 210	7 695 000	1.0	39.1
RECAPITULATION.								
Europe	228 645.5	236 080.5	237 668.7	238 871.8	4 244 420	472 894 000	5.6	5.1
America	371 505.0	372 128.9	372 912.7	373 535.4	15 942 230	214 556 000	2.4	17.4
Asia.	77 961.6	78 052.5	81 294.2	84 253.2	16 303 940	1 007 315 000	0.5	0.8
Africa	35 304.5	35 482.2	36 457.7	37 481.7	9 448 690	112 382 000	0.32	3.4
Australia	29 446.6	29 628.7	29 986.0	30 110.3	3 092 210	7 695 000	1.0	39.1
Total for the World.	742 863.2	751 372.8	758 319.3	764 252.4	49 031 490	1 814 842 000	1.6	4.2

(¹) Corrected figure.

[656 .222.1 (.42 + .44)]

2. — A comparison of British and French train speeds.

(The Railway Gazette.)

In view of the references made to railway speeds in the paper read recently by Mr. Raymond Carpmael before the Institute of Transport, entitled « Safety and Speed on the Railways », it is of interest to compare the highest scheduled speeds of this country with those now obtaining on the mainland of Europe. At present, Germany does not enter into any such comparison, as she has not yet recovered from the slump in railway speed brought about by the late war. There are indications that the serious inroads made by aerial transport on long-distance railway traffic in Germany will soon make railway acceleration inevitable, if the best-class traffic is to be retained, but at present average start-to-stop railway speeds much in excess of 50 miles per hour are infrequent. This reduces the speed comparison to one between the railways of Great Britain and those of France. In France, there has of recent years been a very marked expedition of railway services, even on lines which hitherto have displayed but little interest in fast travelling. On the « Chemin de fer de l'Etat », for example, it is now possible to cover the 100.8 miles from Rennes to Le Mans in 117 minutes, at an average speed of 51.7 miles per hour, and the 86.7 miles from Paris to Rouen in 102 minutes, the latter average of 51.0 miles per hour including a severe slack through a tunnel now in course of reconstruction.

It is, however, with the higher speeds that this article is chiefly concerned. The two tables reproduced give a complete list of runs in Great Britain and France which are scheduled at speeds of 58 miles per hour and over. In the British table 32 runs figure, and in the French table 16 runs. Owing to the custom of slipping coaches prevalent on the Great Western Railway, however, certain runs become duplicated; if these duplications are eliminated, the number of start-to-stop runs included in the British table becomes 26, as several of the trains concerned make more than one high-speed run in succession; also the actual number of trains involved is 23, divided up in the proportion of 14 on the Great Western Railway to 5 London Midland & Scottish Railway and 4 London & North Eastern Railway trains. The mileage covered by these 23 trains at average start-to-stop speeds of 58 miles per hour and over totals 2 101.9 miles; the proportionate division in this case is 1 451.2 miles over Great Western Railway metals, 444.0 miles over those of the London Midland & Scottish Railway, and 206.7 over the London & North Eastern Railway. A corresponding analysis of the French runs gives the credit for 14 of the 16 high-speed journeys to the « Chemin de fer du Nord », and the remaining two, both performed by the same train, to the Midi Company; out of a total mileage of 1 686.0, the Nord claims 1 556.2 miles and the Midi 129.8 miles. It is worthy of note that the Nord figure is 105 miles in excess of that shown by the Great Western Railway, which shows the highest standard of speed in Great Britain.

On the « Chemin de fer du Nord » there are at least twelve expresses which maintain an average rate of 60 miles per hour for 90 miles or over continuously, even though certain of these runs do not figure in the French table owing to difficult portions of their journeys, over the sections most remote from Paris, requiring lower average speeds. For example, the Paris-Aulnoye, Paris-Jeumont, and Paris-Brussels runs are all timed at 60 miles per hour between Paris and St. Quentin; on the Paris-Dunkerque runs the allowance of 120 minutes in each direction over the 119.4 miles between Paris and Arras entails an average rate exceeding 60 miles per hour for more than 100 miles of the distance; the 10 a. m. and 12 noon Calais boat trains, with 110 minutes for the 109.1 miles to the Abbeville stop, require an average rate of exactly 60 miles per hour until slowing down for the stop begins; and the « Golden Arrow » Pullman expresses

Table I. — **British railway runs timed at over 58 miles per hour start-to-stop.**

RAILWAY.	Train.	From	To	Distance.	Time.	Speed.
				Miles.	Minutes.	Miles per hour.
Great Western Railway.	(1) 5.55 p. m.	Swindon	Chippenham.	16.7	16	62.5
— —	3.45 p. m.	Swindon	Paddington	77.3	75	61.8
— —	(1) 11.15 a. m. (1) 1.15 p. m.	Paddington	Bath.	106.9	105	61.6
London & North Eastern Railway	9.01 p. m.	Darlington	York.	44.1	43	61.5
— —	4.30 a. m.	Leicester	Nottingham (4)	22.6	22	61.5
Great Western Railway.	5.55 p. m.	Swindon.	Bath.	29.6	29	61.2
London & North Eastern Railway	5.49 p. m.	Aylesbury.	Leicester	65.1	65	60.1
— —	3.40 a. m.	Brackley	Rugby.	23.9	24	59.8
— —	4.06 a. m.	Rugby.	Leicester	19.9	20	59.7
Great Western Railway.	(1) 10.30 a. m. 12.00 noon	Paddington	Exeter.	173.7	175	59.6
— —	11.15 a. m. 1.15 p. m.	Paddington	Bristol (2).	118.3	120	59.2
London Midland & Scottish Railway.	9.21 a. m.	Willesden Jc.	Birmingham	107.5	109	59.2
	4.50 p. m.	Birmingham.	Willesden Jc.			
Great Western Railway.	(1) 10.30 a. m.	Paddington	Taunton.	142.9	145	59.1
— —	11.45 a. m. 5.15 p. m.	Bristol (3).	Paddington	117.6	120	58.8
— —	(1) 9.42 a. m.	High Wycombe.	Leamington.	60.8	62	58.8
— —	4.30 p. m.	Paddington	Swindon.	77.3	79	58.7
— —	(1) 9.42 a. m.	High Wycombe.	Banbury.	41.0	42	58.6
— —	(1) 10.30 a. m. (1) 3.30 p. m.	Paddington	Westbury.	95.6	98	58.5
London Midland & Scottish Railway.	9.04 a. m.	Luton.	Kettering	41.0	42	58.3
London & North Eastern Railway	7.31 p. m.	Woodford.	Aylesbury.	31.1	32	58.3
London Midland & Scottish Railway.	2.20 p. m. 5.50 p. m.	Euston	Coventry	94.0	97	58 2
Great Western Railway.	4.10 p. m.	Paddington	Leamington.	87.3	90	58.2
— —	5.00 p. m.	Paddington	Kemble	91.0	94	58.1
— —	2.18 p. m.	Evesham	Worcester.	35.8	37	58.1
— —	1.10 p. m.	Swindon.	Paddington	77.3	80	58.0

(1) By slip carriage. (2) Via Bath. (3) Via Badminton. (4) Arkwright Street station.

Table II. — **Daily runs on French railways at over 58 miles per hour start-to-stop.**

RAILWAY.	From	To	Distance.	Time.	Speed.	Train.
			Miles.	Minutes	Miles per hour.	
Midi.	Bordeaux	Dax	91.8	89	61.9	Sud express.
Nord	Paris	Saint-Quentin	95.2	94	60.7	Berlin express.
—	—	Aulnoye	134.0	135	59.5	Amsterdam express.
—	—	Abbeville	109.1	110	59.4	Calais boat expresses (²).
—	—	Arras	119.4	121	59.2	Lille express.
—	Paris Jeumont	Jeumont Paris	147.8	150	59.1	Nord express.
—	Paris	Etaples	140.8	143	59.1	Boulogne boat express.
—	—	Compiègne	52.0	53	58.8	— — —
—	Arras	Longueau	41.1	42	58.7	— — —
—	Etaples	Amiens	59.5	61	58.5	...
—	Aulnoye	Saint-Quentin	38.8	40	58.2	...
—	Paris Calais	Calais Paris	184.3	190	58.2	*Golden Arrow.*
Midi.	Dax	Bayonne	31.0	32	58.0	Sud express.

Table III. — **Other long and fast French runs.**

RAILWAY.	From	To	Distance.	Time.	Speed.	Train.
			Miles.	Minutes.	Miles per hour.	
Nord	Dunkerque	Paris	193.9	203	57.3	Tilbury boat express.
Est	Bar-sur-Aube	Châlons	50.5	53	57.2	...
—	Paris	—	107.0	113	57.0	...
Nord	—	Dunkerque	193.9	205	56.8	Tilbury boat express.
Est	Chaumont	Troyes	59.4	63	56.7	Basle express.
—	Paris	—	103.3	110	56.4	— —
Orléans	—	Les Aubrais	73.9	80	55.5	Sud express.
Nord	Paris Brussels	Brussels Paris	193.0	210	55.2	*North Star.*

have 156 minutes on the coast-bound journey and 157 on the inward for the 156 1/2 miles between Paris and the Outreau Junction at Boulogne. No other railway in the world can equal these figures. The Great Western Railway, with the inclusion of the two down 175-minute runs to Exeter, timed at 60.4 miles per hour between Southal and Exeter, has only seven 60-mile per hour timings over distances exceeding 90 miles : the two runs just mentioned, the four Bristol 2-hour trains (on the down journey from Paddington to Bath and on the up from Badminton to Paddington), and the 3.55 p. m. down South Wales express, as between Southall and Badminton.

Many of the French runs are the more notable on account of the single-headed loads carried. The full load of the « Golden Arrow », consisting of ten 77-foot Pullman cars and a bogie brake, is 500 tare tons; the 58.1-miles per hour average speed of this train over the 184 miles between Calais and Paris includes the 8-mile ascent to Caffiers Summit, at 1 in 125 — equal in steepness to the worst of the ascent up the north side of Shap Summit in Westmorland — and then the 60-miles per hour average previously mentioned between Boulogne and Paris, including long ascents at 1 in 300 from Amiens to Gannes, and at 1 in 200 from Creil to Survilliers, and service slacks through Abbeville and Amiens, the latter very severe. The « super-*Pacific* » compound locomotives working these trains are equal in weight to the rebuilt *Pacific* engine *Enterprise*, of the London & North Eastern Railway, and maintain the high speeds demanded by these bookings, including sustained speeds of over 70 miles per hour on the level, despite being fired with briquettes. The fastest run in France is that of the Sud Express over the Midi line between Bordeaux and Dax, averaging 61.9 miles per hour, and it is worthy of comment that the haulage in this case is electric. As regards length, the non-stop Paris-Dunkerque run of the boat expresses on the Tilbury service now just beats the previous Continental record of 193 miles between Paris and Brussels, being 193.9 miles in length. Tenders of very large water capacity have to be provided for these four lengthy runs, as no water-troughs are available *en route*.

From the British table it will be seen that in our own country there are now six daily runs timed from start-to-stop at over 60 miles per hour; the figure of six includes the Swindon-Chippenham slip journey in the Swindon-Bath run of the 4.30 p. m. train from Paddington to Bristol, from which the slip is detached. Out of the five London & North Eastern Railway journeys included in this table, three are made by the same express — the 2.32 a. m. down newspaper train from Marylebone, which makes three runs in succession, timed at practically 60 miles per hour, from Brackley to Rugby, Rugby to Leicester, and Leicester to Arkwright Street, Nottingham. As showing to what extent present-day locomotives have time in hand even on such bookings as these, the writer has in his possession details of a run made on the 3.45 p. m. from Swindon to Paddington, allowed 75 minutes for the 77.3 miles' journey, in which a late start from Swindon was recouped to the extent of completing the trip in 66 minutes 12 s., or nearly 9 minutes under schedule time, at an average rate of exactly 70 miles per hour throughout. From the safety point of view it is significant that the Great Western Railway, which sets the highest speed standard in this country, has also the best record for freedom from accident, having suffered no mishap to a passenger train involving loss of life for 23 years past, during the course of which most of these high-speed bookings have been initiated.

[625. 143.3 (.43)]

3. — Effect of unsprung car weight on track wear.

Figs. 1 to 3, pp. 617 and 618.

(*Electric Railway Journal.*)

Effects of reduction of unsprung weight on rail wear, particularly at joints and in special work, in connection with electric cars equipped with bevel gear drive, have been studied by the

Berlin, Germany, Surface Lines, which operates a number of such cars. Measurements were made with a vibration meter to determine the extent of the blows delivered by the wheels of cars of about the same total weight but with different proportions of unsprung weight. The results are given in an article by Ph. Kramer, one of the engineers of the Berlin Surface Lines, and published in the issue of 28 January 1928, of the *Zeitschrift des V. d. I.*

The tests were made by operating cars of different types across an electric railway over steam railroad crossing. The electric railway rails at this point are flange-bearing, so the electric car wheels run on their flanges up to the point where the groove in the steam railroad rail occurs. Here the electric railway wheels, which were of 28.4 inches diameter, in passing over the steam railroad groove with a width of 1.57 inches were able theoretically to drop a maximum of 0.006 inch.

The cars tested were of the following types :

1. A single-truck car with motors suspended in the usual way from the axles. The weight of the car empty was 24 640 lb.; the gear ratio was 1: 5.92; unsprung weight per axle 2 486 lb.; wheel diameter, 28.4 inches; wheelbase, 9 ft. 2 in.

2. A car similar in type, spring support, etc., to the one just mentioned, but with spring-supported motor and bevel gear with double reduction. The gear ratio was 1 : 6.03 and the total weight was 26 114 lb., of which the unsprung weight, including gear cases and axle journals, was 2 182 lb. per axle. The wheel diameters and wheelbase were the same as in the first car.

3. A car mounted on two maximum traction trucks drawing an empty four-wheel trailer. The data of the maximum traction truck car were: wheelbase, 51 inches; truck base, 18 feet; wheel diameters, 31 1/2 an 22 inches; total weight 33 880 lb. The trailer data were : total weight, 15 400 lb.; wheel diameter, 28.4 inches; wheelbase, 9 ft. 2 in.; unsprung weight, 1 320 lb. per axle.

The vibration meter, which was somewhat similar in design to a seismograph, registered the vibrations in a vertical and in two horizontal directions. The diagram (fig. 1) shows the result of a number of readings in which the ordinates are the geometrical sum of the vibrations in the three different directions (vertical and two horizontal), measured in millimeters, and the abscissas are the speeds in kilometers per hour. Tests were made with both loaded and empty cars, as shown in the table. It will be seen from the tests with empty cars that the car with bevel drive caused less vibration than the one with axle suspended motors, and with loaded cars this was the case for speeds of more than 12 1/2 km. (7 3/4 miles) per hour.

Up to speeds of 34 km. (21 1/4 miles) per hour, the double-truck car caused considerably

Data of cars tested.

TYPE OF CAR.	Total weight.		Unsprung weight per axle.	
	Metric tons.	Pounds.	Kilograms.	Pounds.
Car with axle suspended motors.	11.2	24 640	1 380	3 036
Car with axle suspended motors and 500 kgr. (1 100 lb.) extra unsprung weight	11.7	25 740	1 380	3 036
Car with beveled gear motors	11.87	26 114	992	2 182
Car with beveled gear motors with 3 tons load.	14.87	32 714	992	2 182
Maximum traction car	15.4	33 880	...	...
Trail car with four wheels	7	15 400	600	1 320

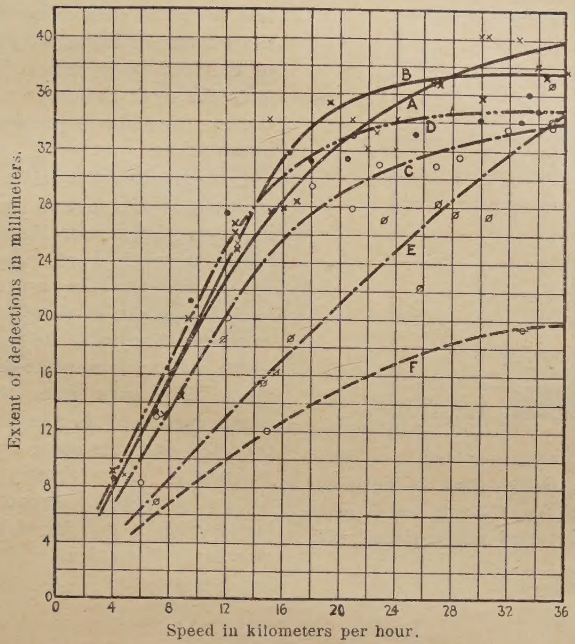
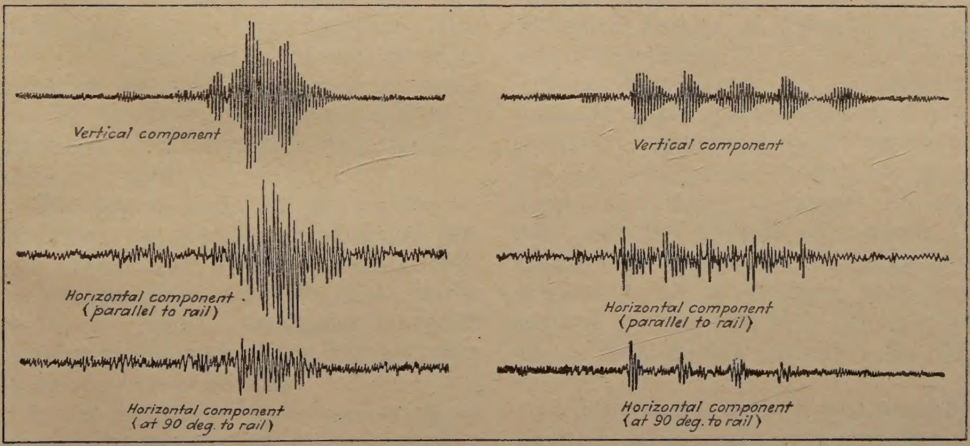


Fig. 1. — Chart showing the geometrically added deflections in the direction of the three components (vertical and two horizontal) for various cars at various speeds, viz. : A, axle-suspended motor car, empty; B, same with 500 kgr. (1 100 lb.) extra unsprung weight; C, beveled-gear motor car, empty; D, same with 3 000 kgr. (6 600 lb.) regular load; E, maximum-traction truck car; F, four-wheel trail car.



Records made with the car traveling at 27 km. (17 miles) an hour.

Records made with the car traveling at 8.8 km. (5 1/2 miles) an hour.

Fig. 2. — Typical records obtained with the vibration meter when a car passed over the crossing.

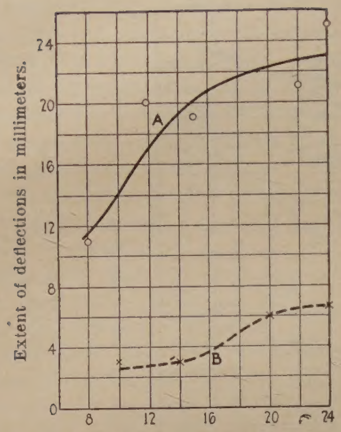


Fig. 3. — Comparison of the blows on the motor when A) it is supported on the axle and B) when it is fully spring supported and equipped with bevel gear.

less vibration than either of the others, though the number of blows was, of course, twice that of the four-wheel cars. The trailer naturally gave the most favorable results. The data of the cars tested are presented in the accompanying table.

One great merit claimed for the spring support of the motors is that it reduces the shock to the motors themselves, as compared with the method of supporting one end of the motors on the axles. Tests to determine the extent of these blows were also made in conjunction with the State Railway Department, with a somewhat different type of machine. The cars were the same two four-wheel cars used in the other tests and were operated over the same crossing. The curves reproduced show greatly reduced shocks on the car with spring supported motors, as compared with a car in which the motors were sleeved on the axles.